Medical
Walter

VOL. IX, No. 1 JANUARY, 1927 Old Series Vol. XXV, No. 1

# The Journal of Bone and Joint Surgery

## AN OPERATION FOR STABILIZING PARALYTIC HIPS

### A Preliminary Report

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Instability of the hip joint, due to paralysis of the gluteus maximus and medius, is one of the most crippling deformities which result from anterior poliomyelitis. Instability of the hip causes a lurching gait which interferes with locomotion and is unsightly. In addition, such instability throws an unusual burden on the knee joint, which itself is usually weak because of paralysis or impairment of some of its supporting muscles. The result is that a knee joint, which would be capable of weight-bearing, becomes incapable of functioning properly with the added burden of the unstable hip to overcome. Frequently, when a brace is applied to support such an over-burdened knee, the effectiveness of the apparatus is nullified to a large extent by the unstable hip.

Such being the results of an unstable hip, it is to be expected that many efforts have been made to overcome this condition, and a number of operative procedures devised for its relief. The operation here reported has been used in our clinic for the past five years to give stability to a hip joint, which, because of paralysis of the glutei, is unstable and interferes with locomotion. The procedure seeks to replace in part the paralyzed stabilizers of the hip, the glutei, by utilizing the tensor fasciae femoris. This muscle in function is admitted to be closely associated with the gluteus maximus; it has also some action in common with the gluteus medius. So far as its relation to the gluteus maximus is concerned, they are both tensors of the fascia lata, and, in addition, both serve to steady the condyles of the femur on the articular surface of the tibia and support the knee in the extended position when the extensor muscles of the knee are relaxed. In common with the gluteus medius, the tensor fasciae femoris, in the erect position acting from below, serves to steady the pelvis upon the head of the femur, according to Gray. As these muscles are so closely associated in function, we felt that if the action of the tensor fasciae femoris could be

utilized more advantageously, it should serve to replace, in part at least, the action of the gluteals when the latter were paralyzed. A transplantation of the origin of the tensor fasciae femoris from just external to the anterior superior spine to the vicinity of the posterior superior spine should, we felt, result in using the power of this muscle to a better advantage for two reasons: First, in such a position, the pull of the muscle would be in almost the same direction as that of the gluteus maximus and so should in part replace it. Second, the muscle pull should in its new direction act to steady the pelvis upon the head of the femur, thus to some extent replacing a weak or paralyzed gluteus medius. This procedure was then carried out and proved to be feasible. The results have been uniformly successful and a brief preliminary report seemed worth while.

Procedure: (1) With the patient lying well over on the side, the skin incision is made. This starts at the anterior superior spine and runs posteriorly along the crest of the ilium to the posterior superior spine. Anteriorly, it is prolonged downward from the anterior superior spine onto the thigh for a distance of about four inches, passing along the inner border of the tensor fasciae femoris (lata). The skin and subcutaneous fat are reflected back, exposing the fascia covering the tensor fasciae femoris (lata), the gluteus medius and the gluteus maximus (Fig. 1—Insert).

(2) The tensor fasciae femoris is next separated from the sartorius and rectus femoris anteriorly for a distance of about four or five inches, and from the gluteus medius for about three inches posteriorly; care should be taken in this dissection not to interfere with the nerve supply to the muscle. The nerve to the tensor fasciae femoris, coming from the superior gluteal nerve, emerges from beneath the gluteus medius at about its lower third and passes into the under surface of the muscle.

(3) The tensor fasciae femoris (lata), having been freed well down towards the knee, is separated from its origin at the crest of the ilium by chiselling off a shell of bone. As large a shell as possible is taken; usually a good substantial piece about two inches long can be secured (Fig. 1).

(4) The atrophied gluteus medius is now carefully lifted up and through the tunnel thus formed beneath it, the severed insertion of the tensor fasciae femoris (lata) is passed, to emerge through an incision in the fascia made at the anterior border of the gluteus maximus (Fig. 2). This tunnel beneath the gluteus medius should be made close to its insertion into the greater trochanter to allow the transplanted muscle to pass as far posteriorly as possible.

(5) The thigh is now strongly abducted to allow the insertion of the tensor fasciae femoris (lata) to pass well posteriorly and reach the posterior superior spine if possible. It will almost invariably reach this position if the abduction is carried far enough. At this point, a groove is made in the crest of the ilium into which the shell of the bone adherent to the origin of the tensor fasciae femoris (lata) is securely fastened with No. 3 chromicized catgut or silk suture (Fig. 3). If, even with extreme abduction, the tensor fasciae femoris (lata) is too short to reach the posterior superior spine, a

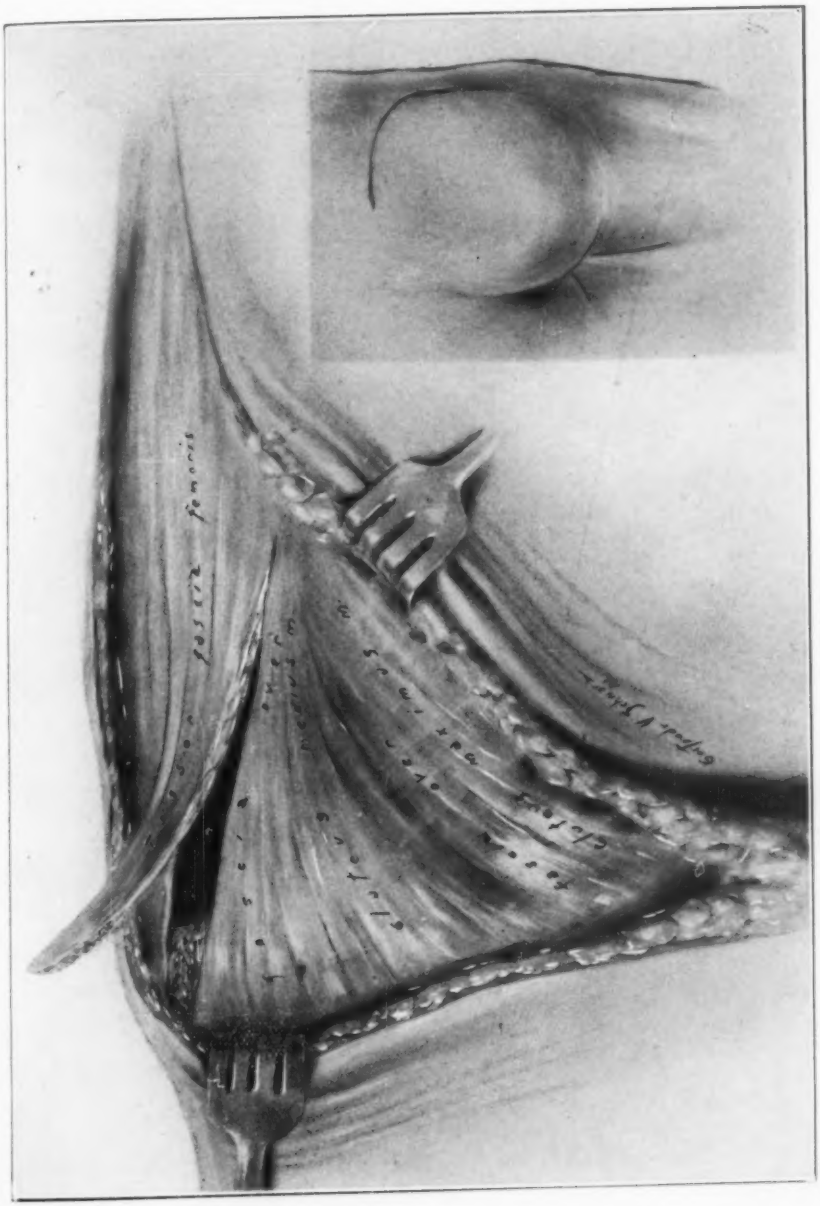

FIG. 1

Tensor fascia femoris partly dissected free and turned back with a shell of bone from the crest of the ilium; fascia covering gluteus medius and gluteus maximus shown intact. (Insert—Skin incision.)

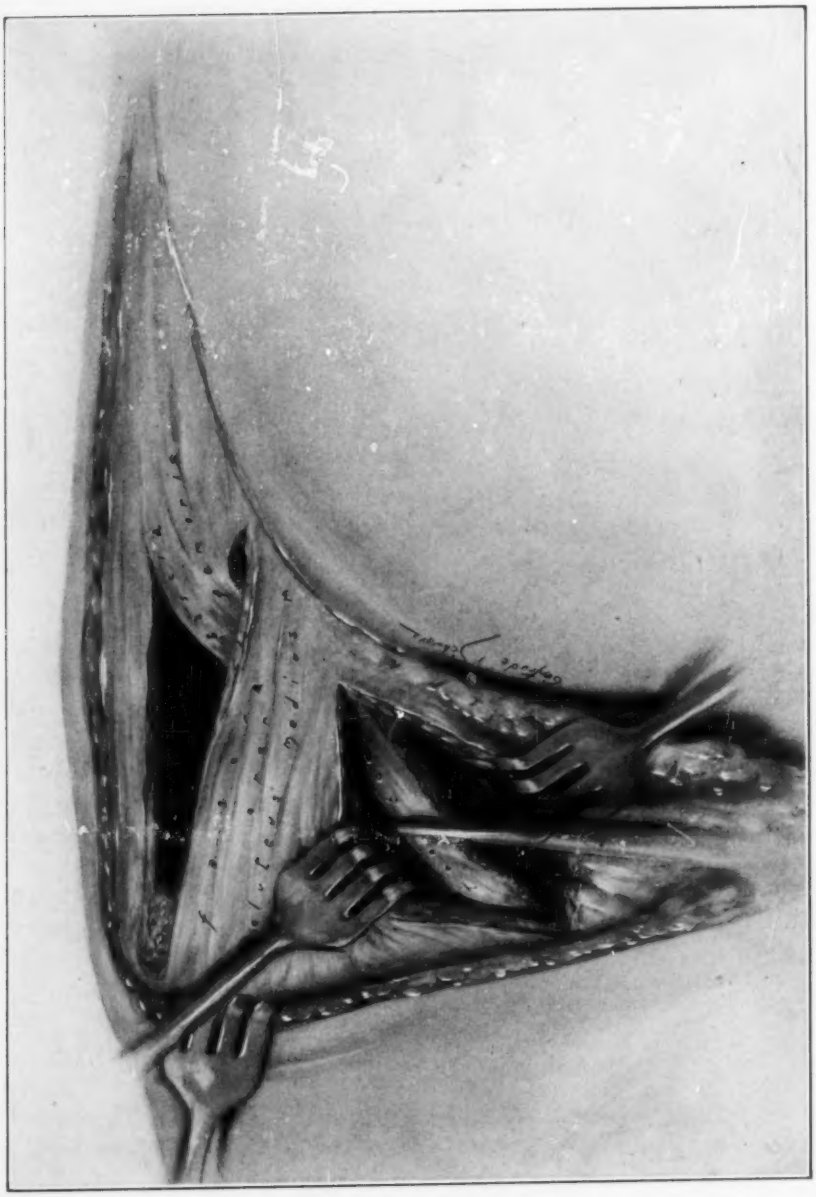

FIG. 2

Tensor fascia femoris passed through the tunnel made by lifting up the gluteus medius. The muscle emerges through a slit made in the fascia at the anterior border of the gluteus maximus.

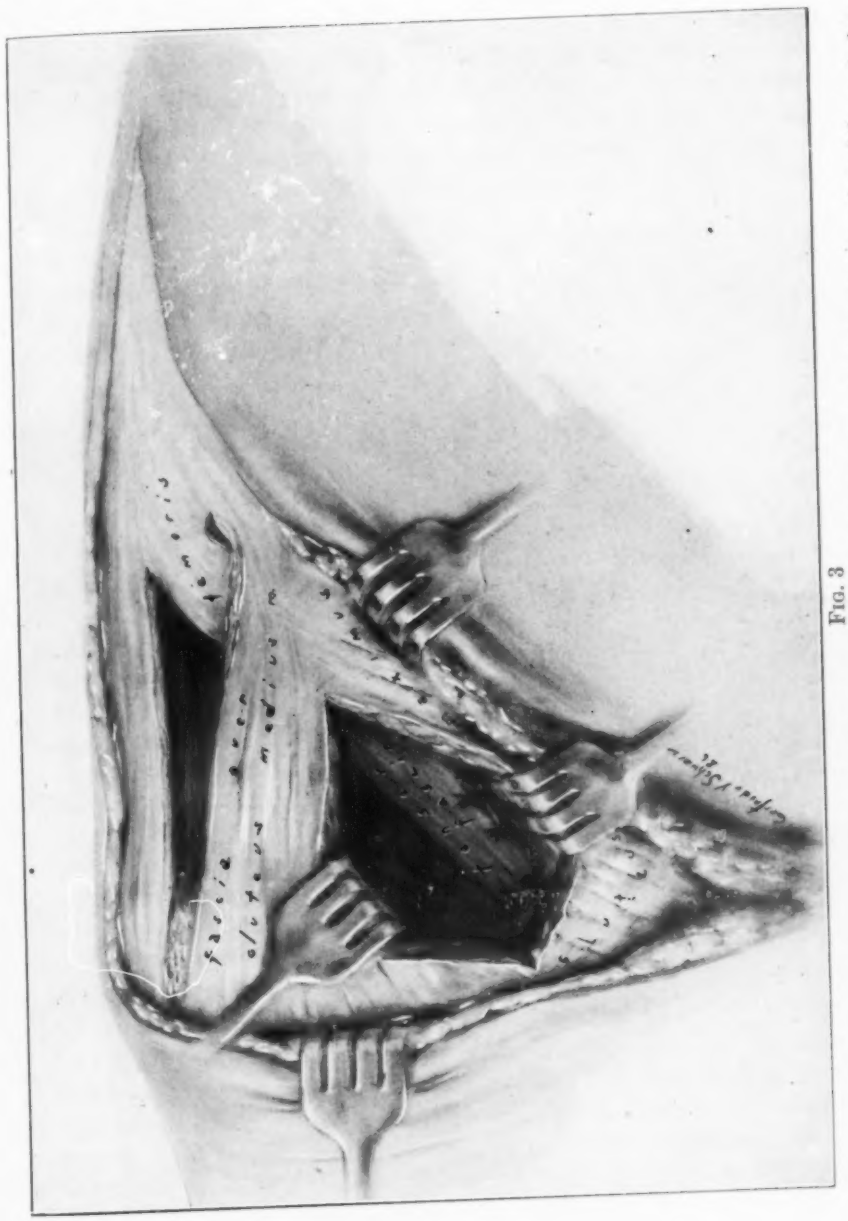

FIG. 3

Tensor fascia femoris has been made fast to the groove cut in the crest of the ilium in the region of the posterior superior spine; stitches attaching its posterior edge to the under surface of the gluteus maximus also shown.

strong band of fascia attached to the crest of the ilium can be turned up, and by suturing the tensor to this, a firm attachment for the transplanted muscle can be secured. Occasionally, when unable to bring the muscle as far posterior as was desired, we have raised a flap from the side of the ilium below the crest and attached the muscle at this point. It is usually only in the older cases that we have found it necessary to resort to fixation below and slightly anterior to the posterior superior spine.

(6) The posterior edge of the transplanted tensor fasciae femoris is then firmly sutured to the under surface of the gluteus maximus, the sutures through the gluteus maximus being placed as far posteriorly as possible, thus drawing the transplanted muscle back and anchoring it (Fig. 3). If the muscle has been displaced as far posteriorly as it should be, it will, in its new position, pass over the anterior half of the greater trochanter.

FIG. 4

This shows the leg in plaster in extreme abduction,—the position in which the leg is most usually put up after operation.

(7) The wound is closed, all dead spaces being carefully obliterated, and the limb put up in plaster in extreme abduction (Fig. 4).

(8) At the end of three or four weeks, the cast is cut down and daily exercises given. The exercises consist in placing the patient in a prone position and teaching him to extend the hip on the pelvis with the thigh abducted. The cast is removed and the extremity allowed gradually to come down from the abducted position at the end of six to eight weeks, and the patient allowed to use the extremity.

As stated, this operation has been performed in our clinic for the past five years, forty cases having been operated upon. At first, we only attempted this procedure in patients in whom we felt sure that there was present an unparalyzed tensor fasciae femoris. Lately, however, we have performed this operation when there was little or no power in the tensor, as we became convinced that the presence of a broad fascial band, placed as this one is, gives a very useful stability to an otherwise unstable hip joint. Of course, if a very weak or paralyzed tensor fasciae femoris is used, we cannot expect voluntary extension power of the hip to develop, but when an unparalyzed muscle is used, an astonishing amount of abduction and extension of the hip joint can be secured through the transplanted muscle. The results, as stated, have been uniformly satisfactory, as the

lurching gait has been eliminated or greatly improved and the stability of the hip secured.

One objection may be made to this procedure; namely, that the nerve supply of the tensor fasciae femoris is the same as that of the paralyzed gluteus medius we are attempting to replace. This, however, is not a valid objection as frequently the tensor fasciae femoris is found unparalyzed even with paralyzed glutei. Whitman has pointed out the infrequency in which the tensor fasciae femoris is paralyzed. Moreover, as stated above, even if paralyzed, it acts very satisfactorily as a stay.

The procedure described here is used to give stability to the hip joint in the following conditions:

(1) Flexion contraction of the hip with paralyzed glutei. Here we have found it advisable at times to follow it later by a modified Soutter operation.

(2) In a relaxed hip joint which subluxates when weight-bearing is attempted.

(3) To hold a definitely luxated hip (due to paralysis) in the acetabulum after reposition.

A later report will take up in detail the entire procedure with case reports.

# ACUTE HAEMATOGENOUS OSTEOMYELITIS

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The vital factors concerning the disease Acute Haematogenous Osteomyelitis are not fully recognized by the medical profession. The disease has so long been regarded as actually what its name implies, that the diagnosis is not made in the early stages. If the disease were an infection of the medulla, as apart from the metaphysis, one would seek for signs of infection in the middle of the shaft. If these signs occur, they are extraordinarily rare. The early signs common to this disease are not to be found in the middle of the shaft.

So much has been written concerning the diagnosis of osteomyelitis and its types, that one would hesitate to attempt further description. The disease is a very common one, and statistics of cases are available from numberless surgical centres dealing with age, sex and frequency of lesions in particular bones. It is not my plan, therefore, to make a statistical study of this disease, but rather to review some of the experimental and pathological work relating to the condition, fitting this into the clinical picture if possible. The disease is so common, the symptoms so typical and the examination so definite, that one is surprised that the diagnosis is ever missed. I believe that if a case can be made for the seat of the infection being in the metaphysis, then the diagnosis will be very much simpler. The signs and symptoms all point to this.

*Experimental Osteomyelitis.* There has been a great amount of experimental work done on animals in an endeavor to produce a condition in long bones analogous to osteomyelitis as seen in the human. In 1884 Rodet produced, without the aid of trauma, abscesses in bone, by the simple intravenous injection of staphylococcus aureus. Other workers attempted similar experiments employing other organisms. Lexer[1] found that a large dose of an emulsion of living organisms—staphylococci—given intravenously to a young rabbit, would cause death within twenty-four hours. He found by giving smaller quantities of the bacterial emulsion that the animals would live several days and die with abscesses in the viscera, muscles, bones and joints. Smaller amounts produced less general reaction and fewer abscesses in the muscles and viscera, and more abscesses in the bones. The abscesses in the bones were most commonly situated in the broad metaphyses, a name given by Kocker to describe the broad extremity of the diaphyses, lying next to the epiphyses. The commonest sites for this infection in bones appeared to be the lower end of the

diaphysis of the femur, the upper end of the diaphysis of the tibia and the upper extremity of the humerus. Concurring in the above, Lexer quotes Rodet, Colzi, Lennelongue, Archard and Ackerman. He writes further that if old attenuated cultures of staphylococcus are used, animals sicken for a short time but recover. During this time local painful swellings occur over bones, and a condition analogous to the infection in man occurs. It is impossible to produce in animals by intravenous injection of staphylocci, an acute progressive medullary phlegmon, unless there has been a previous inflammation due to the injection of some other organism. He quotes Ullman as demonstrating the influence trauma has in determining the location of and contributing to bone infection.

Teruo Hobo[2], in reviewing the experimental work, quotes Koch as demonstrating the localization of infection from intravenous inoculation as occurring in three places of predilection. Using large bacilli, he found these places to be the epiphyses, the metaphyses and the periosteal vascular region. He quotes Dummont as having produced a typical osteomyelitis in young animals, using a staphylococcus aureus from a furuncle. Two hours after injection these organisms were found in the veins of the metaphysis. He believed they lay in the metaphysis and remained active and grew, and became the centre of inflammation.

Hobo studied the anatomical arrangement of the shaft of long bones, and agreed with Langer's description of the blood vessel arrangement. From the nutrient artery, an artery to the metaphysis comes off to run in its direction. These arteries become very small through branching, and, after looping just back of the cartilage line, eventually end in a large venous capillary that runs towards the medulla. He believes that there is a very marked slowing of the stream as a result of this arrangement. The medulla, on the other hand, is extremely rich in blood channels, and especially bountifully provided with cellular elements. When he injected very finely ground Chinese ink into the blood vessels of animals, the particles were found very evenly distributed throughout the medulla. These particles are not found in the arterial branches, but on the venous side. He found in some instances a concentration of particles in the metaphysis when the blood channel suddenly inclined into a large venous capillary. This, however, was not constant, and he found on the whole that the number of particles was strikingly less in the metaphysis than in the medulla. He believes, and attempts to prove, that the medulla is much richer in phagocytic elements than the metaphysis. He demonstrates sections of bones from experimental animals, when, following intravenous injections, focal areas are found in the metaphysis. Sections of bone taken one to three hours after the injection show organisms evenly distributed throughout the medulla. Later bacteria are found in the metaphysis, that are taken up by either endothelial cells or leucocytes. Six hours after injection there is a marked increase of organisms in the metaphysis. In twenty-four hours there is tissue destruction in this region.

He believes that these organisms are at a decided advantage in the

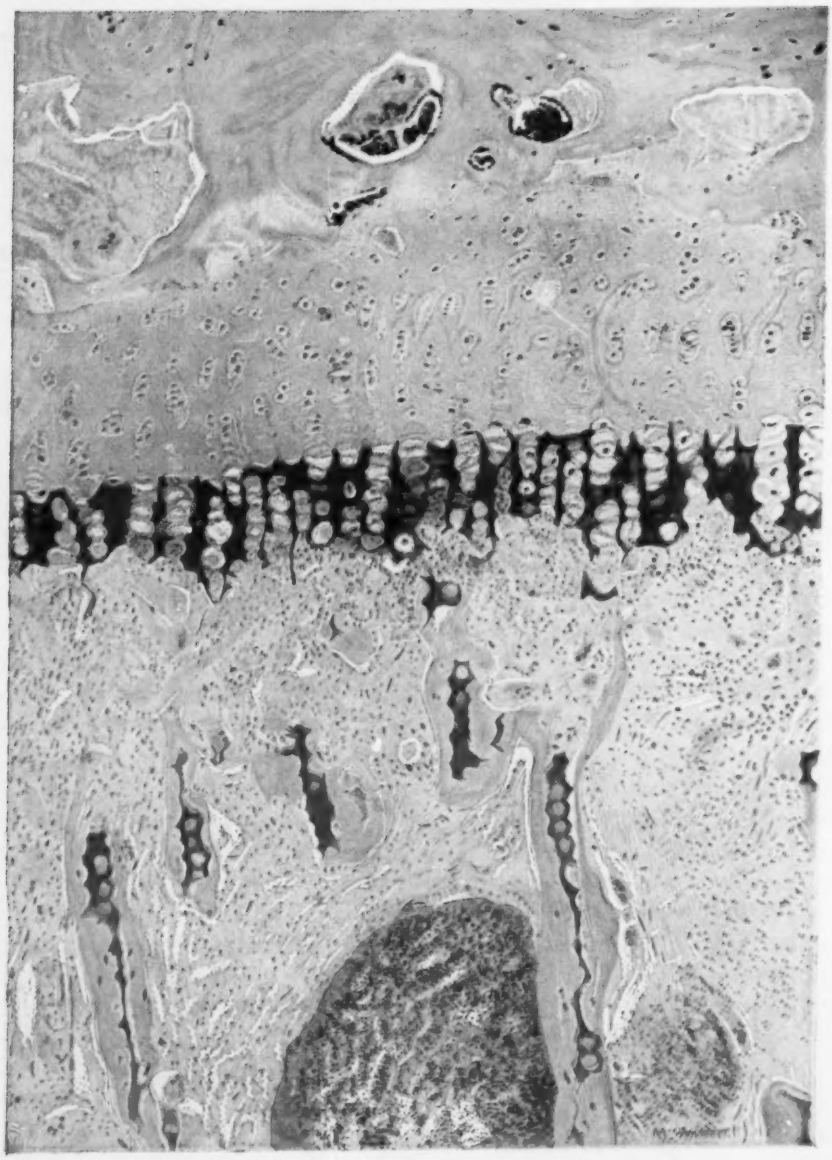

FIG. 1

Animal killed seven days after inoculation. Abscesses in metaphysis and above line of cartilage in plate of epiphyseal bone are spaces filled with solid growth of staphylococci.

metaphysis. There, there are fine narrow channels with rigid walls, and these limit the phagocytic activity in their paucity of phagocyte cells. The cartilage cells harbor the organisms, and here again attack is difficult. From these points of advantage the organisms operate and emigrate.

Weichselbaum showed in patients who had had no demonstrable blood infection, but who had died of pneumonia, erysipelas and felons, the organism of the disease in the bone marrow. One must therefore conclude that when there is a soiling of the blood, the organisms are to be found in the medulla of bones.

The experimental production of osteomyelitis seems only possible in young animals. Lexer states that older animals, as do older people, develop arthritis in the presence of a blood infection. LeMesurier and Harris, demonstrating infection to classes of students, using various organisms intravenously in adult animals, observed no bone abscesses.

In an attempt to verify some of the above experimental work, I obtained some young rabbits, twelve to fifteen weeks of age, and working in the Laboratory of the Experimental Research Committee of the University of Toronto did some experiments of which I quote three. The intravenous injection in these animals was 3 c.c. of an emulsion of staphylococcus aureus, made from a recent culture obtained from a case of acute osteomyelitis in a boy.

EXPERIMENT 3. Animal inoculated through a vein in the ear. Two hours later the animal was killed. Section of the long bones showed a most active phagocytosis throughout the epiphyses and the medulla. Leucocytes containing organisms were found throughout the above, and in some instances the large polynuclear cells present in the medulla were seen to contain one or more leucocytes. There were very few leucocytes or cells containing organ-

FIG. 2

Experiment 5. Microphotograph; × 150. Illustrating an abscess in the epiphysis. The cartilage plate is seen in the left hand lower corner of print.

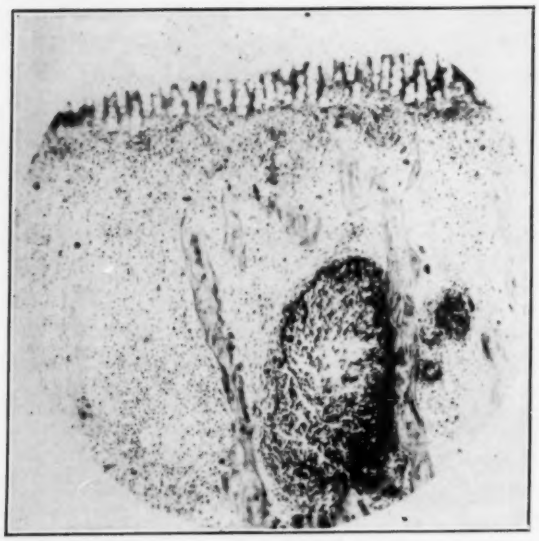

FIG. 3

Experiment 5. Microphotograph; × 40. Abscess seen in metaphysis lying between two bony trabeculae. To the right of the large abscess are to be seen smaller ones. Cellular reaction just below cartilage columns.

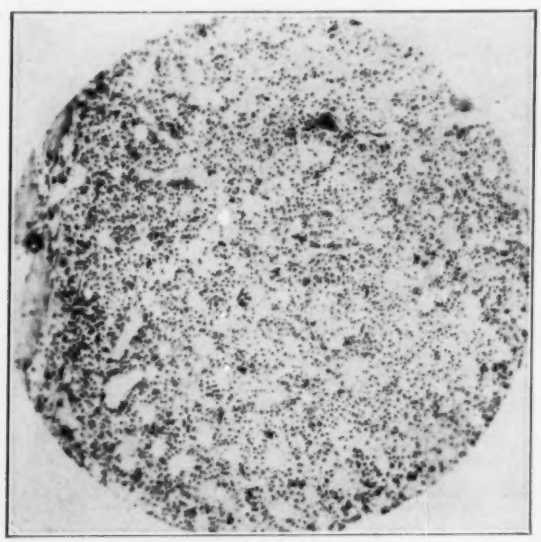

FIG. 4

Experiment 5. Microphotograph; × 40. Microphotograph of middle of medullary canal appears normal. Same bone as Figs. 1, 2 and 3.

isms to be found in that part of the diaphysis lying just below the epiphyseal cartilage.

EXPERIMENT 4. An animal was treated as above, and killed in two hours. A femur was then incubated in an incubator for thirty-six hours. After incubation the bone was sectioned and stained with a Gramm's stain. Large clusters of staphylococci were found throughout the bone. They were very plentiful in the epiphyses and the medulla, and the metaphyses showed large groups. This was in contradistinction to the few organisms seen in the preceding experiment. Here in several places in the periosteum were to be found large groups of organisms.

EXPERIMENT 5. An animal after inoculation was allowed to live for one week. During this time it was fevered, and just before being killed, was very ill. It was unable to walk or stand. Autopsy showed abscesses present in the viscera, muscles, joints and bones. Section of the long bones showed definite abscess formation in three locations only: in the epiphyses, the ends of the diaphyses, metaphyses and in the periosteum (Figs. 1, 2, 3, 4, and 5).

The epiphysis showed a very definite infection, with many clusters of leucocytes, most conspicuous along the bony plate overlying the cartilage. An abscess is to be seen close to the epiphyseal plate (Fig. 2). The epiphyseal plate overlying the cartilage shows channels containing necrotic masses, and others with clusters of organisms obvious to low power magnification. In the carti-

lage plate, the cell cavities in some instances were full of organisms. Where the diaphysis meets the cartilage plate, the section shows marked tissue reaction and some abscesses (Figs. 1 and 3). The remainder of the medulla, while injected, showed in no place tissue reaction, and no abscess was found (Fig. 4). A definite abscess was found in the periosteum (Fig. 5). There was no underlying contiguous infection in the bone.

FIG. 5

Experiment 5. Microphotograph; × 40. Shows a well marked abscess in the periosteum. No underlying contiguous infection found in the bone.

Some years ago a boy was admitted to the hospital who had a well marked osteomyelitis of the lower end of the tibia. The local signs were at the lower end only. With the hope of ascertaining the nature of the infection, if any, of the medullary cavity, I first drilled a hole into the medullary canal through an incision at the middle of the shaft. This hole permitted cultures and swabs being taken. These were negative for pus and organisms. The disease was then attacked at the lower end of the tibia, and pus, being present there in fair quantities, was drained. The experimental work seems to prove beyond any doubt that:

1. Organisms introduced into the blood stream are deposited, among other places, in the long bones.
2. In bone there is very active phagocytosis, except in the metaphyses.
3. Organisms produce inflammatory centres in metaphysis independent of trauma.
4. It is impossible to produce a general infection of the medulla by a simple inoculation of organisms into the blood stream.
5. Trauma may determine a local infection.
6. Growing bones develop abscesses of the type of osteomyelitis within them. Adult bones do so but rarely. In the presence of a bacteriemia, adults may produce an arthritis.

*Human Infection:* The question of the point of entry of the infection is one that involves the blood stream. The infection in most cases is blood borne, except in a few instances where there is direct infection of the periosteum and the superficial bone from a superficial infection in the soft tissues. The entrance of the infection to the blood stream is easily accomplished. Through broken or diseased mucous membrane or through skin in a similar

condition, organisms find easy access to the blood stream. Patients suffering from furuncles not infrequently have organisms gaining entrance to the blood.

Walton Martin[4], as does Lexer also, quotes experiments by Wyssokowitsch, wherein he describes experiments in animals where organisms were introduced into the blood stream. During the first hour or two the organisms rapidly disappeared, so that blood cultures taken shortly afterwards were negative, negative even in a case that subsequently proved fatal. "In a rabbit injected with a large dose of anthrax bacilli, at the end of five minutes only, fifteen colonies were found in the withdrawn blood. At the end of two and a half hours there were no colonies; at the end of forty-six and a half hours three colonies; at the end of seventy hours, fifty-six colonies; at the end of eighty-four hours death followed with countless numbers of bacteria in the blood stream."

This would tend to show that on the introduction of organisms to a blood stream they are shortly after their introduction absent from the circulating blood. In the second experiment of my series, sections of bone from animals killed two hours after being given 3 c.c. of an emulsion of staphylococcus aureus, show the organisms to be found within phagocytic cells, and these appear to be equally distributed throughout the medulla and epiphysis.

It has been demonstrated experimentally that small doses of an organism produce a less violent reaction and lead to a localization. In the case of organisms entering the blood from a superficial skin lesion, for example, they probably do not enter in large quantities. Being deposited in a favorable spot, such as the metaphysis, they escape vigorous phagocytosis and are able to live, reproduce, and become the factor in reinfecting the blood stream and maintaining it in this condition.

*Trauma:* It would appear from the experimental work that has been done that trauma is not an essential factor in the production of the disease. It is frequently observed that the lesions occurring in bone are multiple. In cases that progress to a fatal issue, the bone lesions are practically always multiple. In such cases it is quite evident that trauma is most unlikely to have any relation to the production of the supplementary lesions that make their appearance following the original one. From a clinical standpoint, there seems to be no doubt but that trauma produces, or bears some close relation to the initial bone lesion. The nature of that trauma is not fully realized. The injury is not the sort that follows from a blow directly over the shaft. This type very rarely becomes the site of infection of the underlying bone. The trauma is an injury to the epiphysis.

In the long bones, the epiphyses are at the ends and the cartilaginous epiphyseal lines are the only non-rigid tissue, the weak tissue in the long bones. Into the epiphysis on these cartilaginous lines are attached the ligaments and capsules that have to do with the stabilization of the joints. These ligaments are extraordinarily strong, so that when great stress is placed upon the limb in the region of the joint it is the common occurrence

to have the epiphysis torn off the diaphysis, this type of fracture being a common fracture to be found in children and youths, and these sometimes become infected, as noted at the Hospital for Sick Children, and mentioned by Rose and Carless[5]. It is found that similar trauma in older people will produce a rupture of the ligament,—the epiphyses being united, the bony structure is stronger than the ligaments.

It is seen therefore that strain applied to a limb is expended mostly on the resilient part, viz., the epiphyses. Children, from the nature and manner of their play, are continually subjected to sprains of various degrees. The ones that are insufficient to cause a complete separation of the epiphysis and the diaphysis may cause a definite injury at the site of the cartilage line, with hemorrhage, injury of cells, and consequent lowering of resistance in this area. This injury is to a certain degree painful, and causes the part to be favored and a limitation of the function of the part becomes obvious. A limp is therefore caused if the injury has been in the lower limb. A history of this is found in practically all the cases of osteomyelitis one examines. The limitation of function lasts for a short time only, and there appears to be a return to normal function. A study of the epiphyseal lines on bones having in mind the attachments of ligaments, will reveal to one the location of injury when any abnormal stress is applied to the limb.

It is therefore commonly found that the stress applied to the knee to cause injury to the epiphyseal line, must be exerted in producing a full extension. This causes a strain and injury to the posterior part of the femoral epiphyses, according to Rose and Carless. The other injury that is common in the region of the knee is an injury directly to the tubercle of the tibia. This tubercle is developed in its upper part from the epiphyses and in its lower part from the diaphysis.

The epiphyses of the lower ends of the tibia and fibula are easily injured by inversion or eversion of the foot. The tarsal bones are liable to injury in their epiphyseal regions, as the calcaneum with its wide posterior epiphysis, the astragalus with its small posterior epiphysis, and the navicular with tubercle epiphyses. The other tarsal bones are developed from one centre, and therefore have no epiphyseal line. The metatarsals and the phalangeals have their epiphyseal lines, and are liable to injury. The clavicle has an epiphysis at its inner end. The scapula has an epiphysis at the vertebral border, and the acromion. These are sites of injury.

The humerus has the epiphysis of the head and trochanter at the lower end, the trochlea and the capitellum. These are all liable to strain.

The radius and ulna have epiphyses at either end, and the metacarpals and phalanges have epiphyses also.

The epiphyses around the hip and os innominatum are interesting from the standpoint of osteomyelitis. The crest of the ilium is one that is easily injured. The anterior inferior spine and the tuberosity of the ischium, especially the latter, are liable to injury and disease. The pubic arch is injured at times also. The upper epiphysis of the femur is one that is very liable to injury and one that is located within the joint cavity.

While trauma may not be an essential to the production of experimental osteomyelitis, yet clinically it would appear to determine the production of a lesion. An injury to tissue that is harboring organisms would appear to turn the balance so that the organisms would, finding the media suitable, and phagocytosis and opposition gone, increase and grow rapidly.

*Diagnosis, Signs and Symptoms:* Inasmuch as the deciding factor in the location of the disease is trauma, the disease is essentially one of an age at which there are still unfused epiphyses. It therefore follows that the age that is commonest is the one at which children play with the greatest abandon. From ten to fifteen years of age is the age at which most cases are seen. All observers agree that boys are more commonly affected than girls.

The history of the patient must be patiently and diligently investigated. There is, in nearly all instances, a definite history of an injury to a joint or its region. This injury is so definite that there is interference with function. This interference with function—a limp, for example,—may last for a few hours or a day. After this time a recovery in function occurs, and the patient is generally apparently well until local symptoms occur at the site of the trauma.

It may happen that at the time of the production of trauma, the same accident may have caused an abrasion of the skin. It is not uncommon for this abrasion or cut to become infected and produce a definite "festering, bealing" or an inflammation from which "matter" is seen to exude. A very common skin lesion is an infected blister on the foot. It is a clinical fact that the bone infection does not manifest itself at the time when the skin infection is at its height. The focal infection becomes evident when the superficial lesion is healed, or well on its way to healing. If there has been no skin abrasion with infection, there may have been a furuncle.

This type of skin lesion is practically constant in cases of staphylococcal osteomyelitis, but the lesion may not have been noted by the patient or friends, so that it is very important to make a careful search for a wound just healing. In the absence of a skin lesion, one must continue his investigations to the mouth and throat and the mucous membranes. It is probable that the streptococcal — the pneumococcal — infection finds entrance to the blood stream in these regions.

The first symptom of the infection in bone is stiffness and pain at the site of the previous "sprain". This stiffness is interpreted as being in or concerning the joint, and soon reaches the stage at which there is definite pain. This advances to the point where movement of the neighboring tissues produces pain, and a rigidity is imposed upon the part, and function is abandoned. At this time general reaction may manifest itself by beginning elevation of temperature, by nausea and restlessness. Within twelve hours of the first symptom, the pain will have become so severe that sleep is precluded. Temperature and pulse have risen to a considerable height, and the part involved is carefully guarded from any movement or trauma. The contour of the part is normal. The pain in this disease shows no

remissions during the first few days. At this time tenderness is definite. In some cases it is extremely difficult to conduct an examination to elicit it. But in this examination lies the hope of making an early diagnosis. One must exclude an arthritis, rheumatic or septic. Osler[6] warned of this. In either of these conditions there is synovial involvement, with all its symptoms. In osteomyelitis there may be limitation of movement of the neighboring joint, but there is no synovial change or arthritis in twelve hours. Tenderness is a definite point, and may be demonstrated over the metaphysis of the bone. This area may be no larger than the area a five cent piece would cover, but it is definite and unchangeable. One may assist his examination very materially by knowing the particular places that are commonly found to be involved in bones. These are the places that are liable to strain.

During the second twelve hours all the symptoms are increased and added to those already present one may find a beginning local change in the soft tissues overlying the involved bone. This local change is first an oedema which later becomes reddened, as the infection spreads out to involve the subperiosteal area and the periosteum. This swelling is always just over the focus in the bone, and does not show in all cases in the first twenty-four hours. In some cases its appearance is as late as thirty-six hours. Once it is observed it is found to progress towards the shaft of the bone and away from the joint. This advance, in a case that is allowed to progress without intervention, is continued until in some cases the entire diaphysis is surrounded by pus, the periosteum being lifted and the epiphysis loosened from the shaft. This condition, however, occurs in few cases, and when it does occur it is the outcome of an infection of ten days' duration or more.

It is a very common occurrence to find, after the first twenty-four hours, another bone lesion occurring. Multiplicity of lesions occur in over seventy-five per cent. of cases, and this is almost as marked a feature of this disease as of rheumatic fever.

The diagnosis of acute haematogenous osteomyelitis cannot be made upon the blood count. It is not unusual for the absolute white count to be between fifteen and twenty-five thousand in rheumatism. Conversely, in a desperate case of osteomyelitis the count may be low.

Roentgenology has nothing to offer in the elucidation of an early diagnosis. The x-ray will not show anything of a definite nature until there is rarefaction of the bone, and this is not definite for days. An x-ray taken in the first days may give the uninitiated a very lamentable false security. Figures 6 and 7 show the x-ray of a case taken on the seventh day. X-rays had been taken previous to this on two occasions in an attempt to get information on which to make a diagnosis.

This disease is not to be confused with acute rheumatic fever. This is the mistake so frequently made, and its being made proves the clinical and pathological point that the disease is at the end of a bone close to the joint. As pointed out above, multiplicity of lesions is common to both

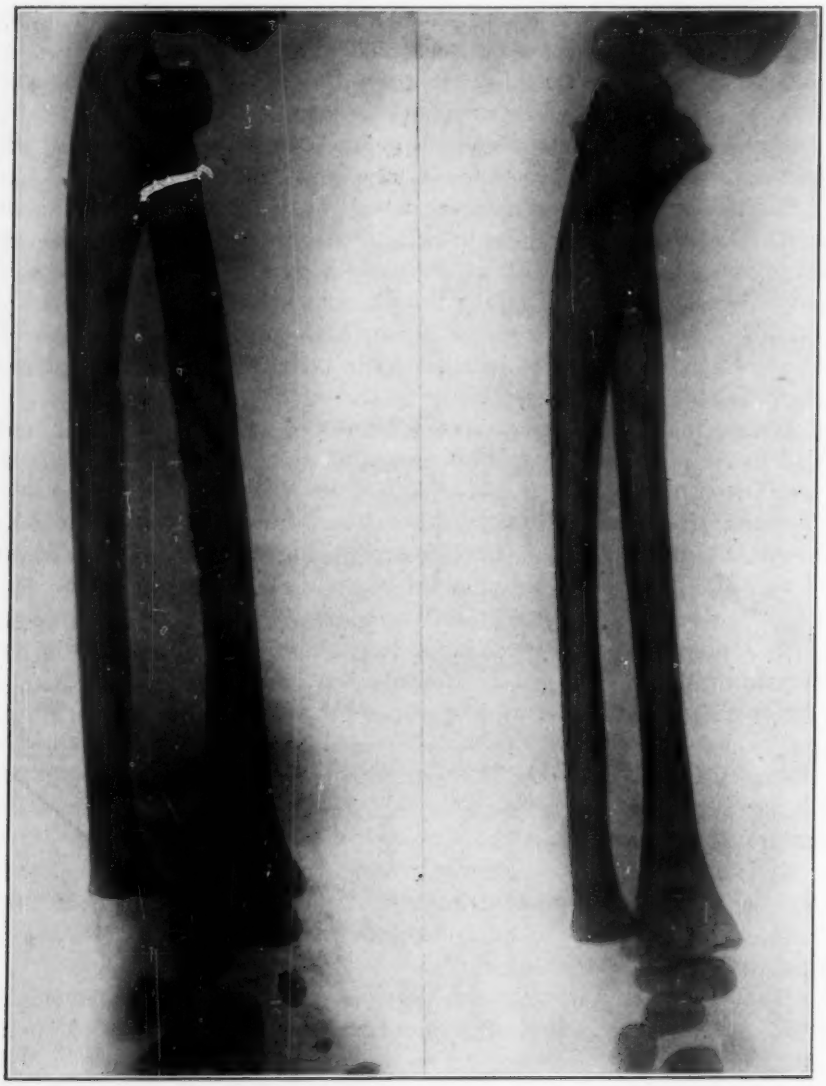

FIG. 6 FIG. 7

Two views of radius and ulna. Osteomyelitis of lower end of radius has existed seven days; now gives evidence of slight rarefaction of lower end of radius at lower metaphysis. Soft tissue swelling evident.

diseases. The pain in rheumatism is not so unremitting as in this disease, and in rheumatism the history is different, and rheumatism is a non-septic arthritis. When a case that has been diagnosed as inflammatory rheumatism or rheumatic fever, presents an abscess, this case is one of osteomyelitis.

The diagnosis of an infection of the upper epiphyses of the femur is

FIG. 8

Osteomyelitis below the upper epiphysis of the left femur. Rarefaction evident. X-ray four and one-half weeks after initial symptom.

extremely difficult. The fact that the epiphyses are entirely within the hip joint adds to the difficulties. The symptoms that develop are those of pain and limitation of the hip joint in association with general reaction and the presence of a healing superficial lesion. In a child or a youth, the diagnosis must be made on aspiration of the hip. If there is no fluid to be withdrawn, that is, if there is no arthritis present and the case be an early one, one has to deal with an acute infection of the epiphysis or the metaphysis. If an infection of the metaphysis is allowed to progress, an arthritis ensues.

Cellulitis, which is said to be a condition that is frequently confused with osteomyelitis, surely does not enter into the picture in the early diagnosis. It is found that the blood gives positive cultures in acute cases, but the results of these cultures may not be available for thirty-six hours, and are therefore not of an early assistance.

*Types of the disease.* Organisms, having gained entry into the blood stream, may produce a disease where the protection of the patient is overcome, and a general infection develops. This is the condition that used to be described by the term septicaemia. There is tremendous general reaction, and, as an incident in this disease and occurring as a supplementary lesion, one frequently sees multiple bone lesions. These cases go on to death, which occurs within a week. The blood of such a patient is at all times highly productive of organisms.

The other type that seems to reach the same condition is the one that develops an outstanding bone lesion which is not relieved. It then

seems to have a general infection develop, and it is possible that this has developed as a result of the continuous soiling of the blood stream from an unrelieved bone lesion.

The next type is the type which is the subject of this thesis. The outstanding lesion is primarily in the metaphysis of long bones, and, if unrelieved, may continue a general infection, or secondarily involve the medulla or periosteum, either by direct spread, or by way of the blood.

The fourth type is the one that shows a typical early localization, but whose process is arrested and no further acute development occurs. This may remain for many years as a small area which is broken down; a bone cavity is thus formed, filled with sterile or infected pus. Figure 14 demonstrates such a case. The upper end of the humerus became very painful; a secondary lesion developed and was drained. The primary one in the humerus quieted down and drained of itself one year later.

FIG. 9

An x-ray taken four weeks after onset of symptoms. It shows a window cut in upper end of diaphysis to permit of drainage of metaphysis. Note no change in lower two-thirds of the shaft.

*Treatment:* This is obviously surgical, and entails the drainage of the lesion. In early cases where the pain is at the metaphysis only and there is as yet no swelling of the soft tissues to disturb the contour of the leg, an incision down to the periosteum reveals nothing abnormal. The periosteum may be found to be oedematous. In this case it is essential to pass drills into the metaphysis parallel to and close to the epiphyses as suggested by Starr[7]. One of these drill holes may tap the inflammatory centre and may have pus exude from it (Fig. 9). It is then essential to remove a small window from the cortex of the bone, and leaving the wound well open, establish in this way free drainage. In a certain percentage of cases this treatment will seem to arrest the disease, as manifested by an improvement in the general condition, with drop in pulse rate and temperature. The blood culture is found to be negative following operation in the majority of cases. The possibility of completely draining each bone space is very remote, but it would seem rational to believe that the drainage of the centre of the lesion would relieve the pressure and so improve the blood supply that the local infection would not spread.

If the case is one that has gone on for days and there is much swelling in the soft tissues, it would then be necessary to establish drainage from a wider area. It would in all

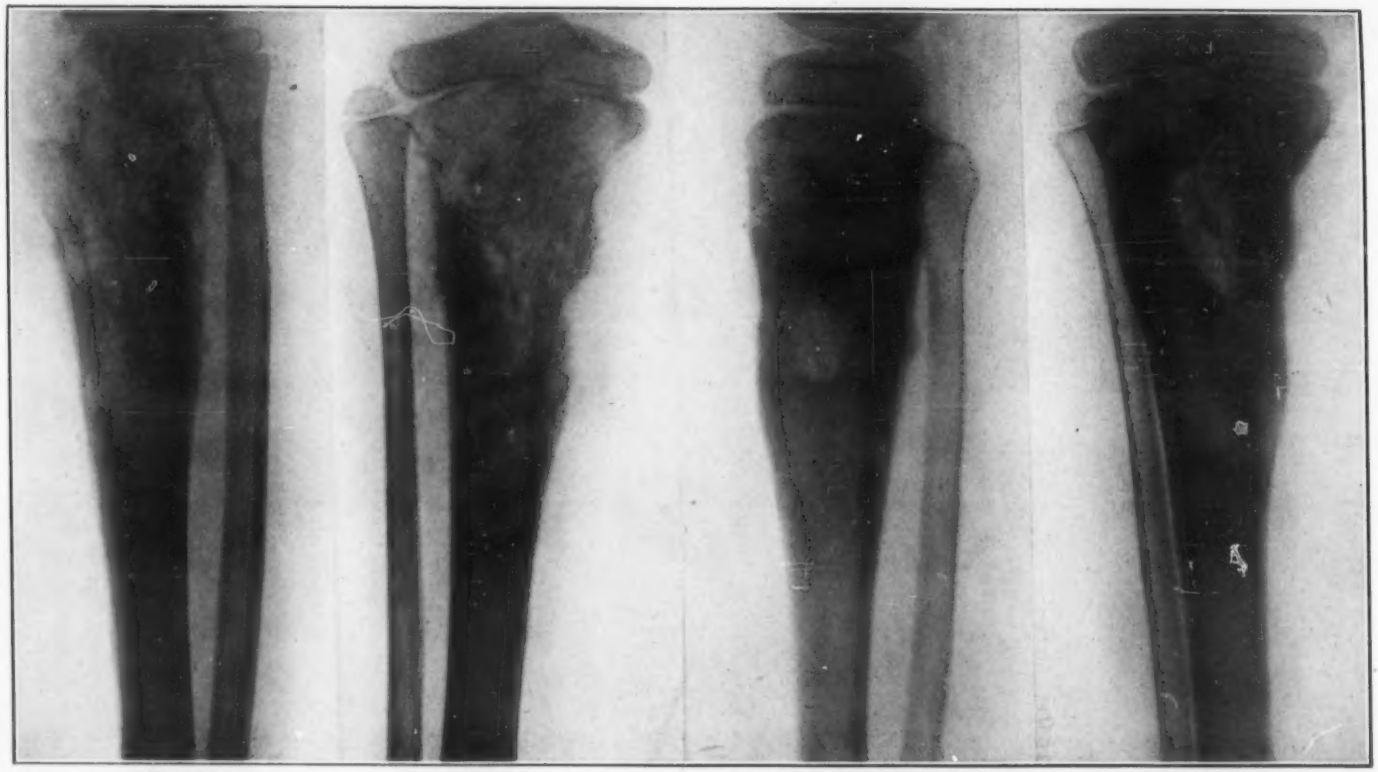

FIG. 10 FIG. 11

These figures are x-rays of the same bones as shown in Fig. 9, taken eight weeks after first symptom.

FIG. 12 FIG. 13

Same case as Figs. 9, 10 and 11. X-ray taken five months after first symptom. Illustrates small bone cavity and small sequestrum. At operation this cavity was two inches long only.

FIG. 14

Osteomyelitis of upper end of humerus, taken one year after first symptom.

probability have invaded secondarily a terminal portion of the medulla. This involved part would therefore have to be drained freely. It may be desired to supplement the treatment of free drainage with some antiseptic solution. Some would like to treat the wound after the Carrell-Dakin method. While I do not consider this of particular merit, yet I would not object to it.

Infection of the neck of the femur calls for special treatment. If one has decided there is an acute infection in the neck it is urgent that the joint be opened to confirm the diagnosis and to treat the condition present. Under any circumstances, whether with or without operation, the joint cavity will be contaminated. If it becomes contaminated, drainage is necessary. I believe it neither possible nor desirable to attempt drainage along the neck of the femur through its base.

After free drainage of the local lesion, it is found that the progress in that bone is limited, if not entirely arrested. Lesions may occur in other bones, and a careful watch must be kept for their appearance. When these do occur they are not so fulminating as the original lesion, but they should be drained as soon as they are recognized.

It is very questionable if one should terminate his operation upon the discovery and drainage of a subperiosteal abscess. The better treatment would be to drain the neighboring metaphysis by taking a window out of the cortex.

After the acute symptoms have subsided and there is no further advance of the disease in the bone, one should maintain drainage in a free manner until sufficient time has elapsed for the sequestrum to have separated from the living bone. One can then interfere, and by making a wide opening, remove this sequestrum and treat the remaining cavity by cauterization. In streptococcal infections one may find a pus very much thinner than in staphylococcal. At the Hospital for Sick Children the former infections are the only type that as a rule do not produce a sequestration.

## CONCLUSIONS

1. Staphylococcal infections come from skin lesions by contaminations of the blood.

2. The primary bone lesion in the human is determined by trauma.

3. Continued septicaemia favors the formation of supplementary bone lesions.

4. The bone lesion is in the metaphysis of a growing child.

5. The chief symptom is pain; the chief sign, tenderness over the involved metaphysis.

6. Treatment—early operation into the metaphysis for purpose of drainage.

## REFERENCES

1. Lexer, Erich: General Surgery, New York and London, D. Appleton & Co., (Bibliography) 236–262, 1908.
2. Hobo, Teruo: Zur Pathogenese der akuten haematogenen Osteomyelitis. Acta Scholae Med. Univ. Imp. Kiota IV, 1, Bibliography, 1921.
3. LeMesurier, A. B. and Harris, R. I.: Personal communication.
4. Martin, Walton: The Conception of Septicaemia and the Fate of Microbes in the Blood Stream. Ann. Surg., LXXXII, 326, Sept. 1925.
5. Rose, William and Carless, Albert: Manual of Surgery. Ed. 8, New York, Wm. Wood & Co., 568, 1911.
6. Osler, Sir William: Practice of Medicine. Ed. 8, New York and London, D. Appleton & Co., 378, 1919.
7. Starr, C. L.: Acute Haematogenous Osteomyelitis. Arch. Surg., IV, 567, May 1922.

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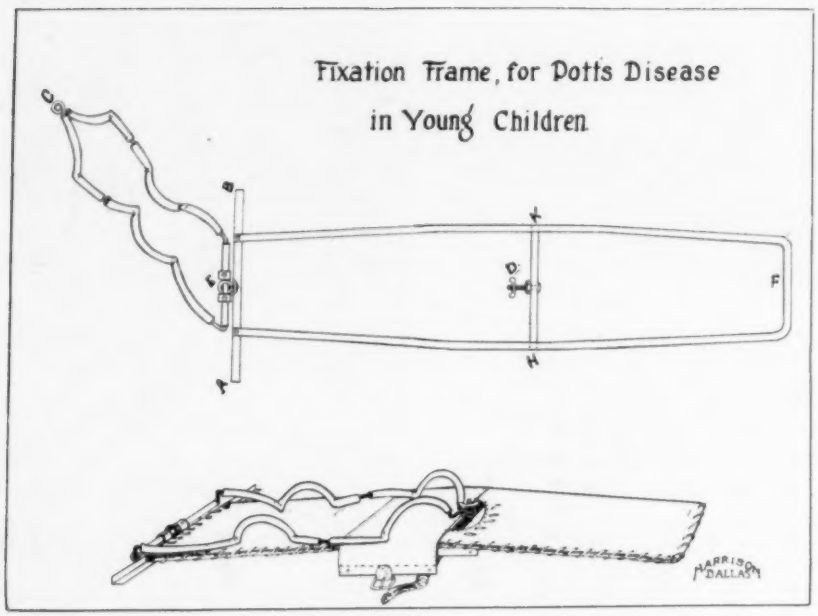



FIG. 1

## FIXATION FRAME FOR POTT'S DISEASE IN YOUNG CHILDREN

BY W. B. CARRELL, M.D., DALLAS, TEXAS

In our effort to avoid the use of plaster in the treatment of Pott's disease we have found a very simple device attached to the frame is adequate for keeping the most intractable child in fixed recumbency. It is equally effective for dorsal or ventral position and has the advantage of leaving the arms and legs free and the body exposed for heliotherapy. Dr.

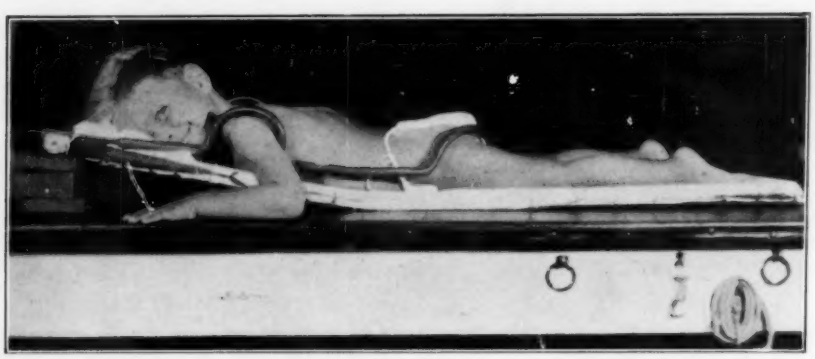


FIG. 2

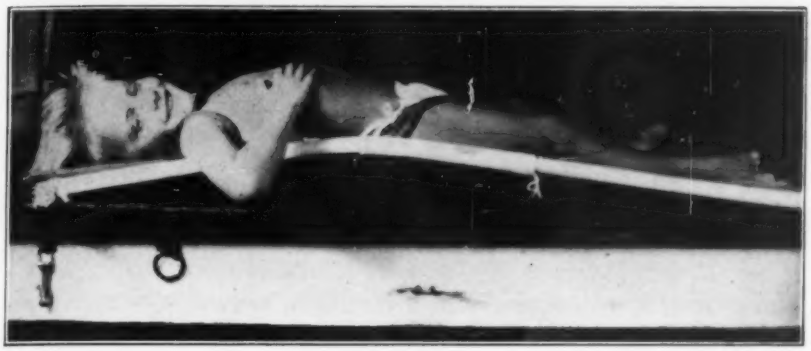


FIG. 3

P. M. Girard, House Surgeon at the Scottish Rite Hospital for Crippled Children, designed the apparatus and the drawings are self-explanatory.

Attachment C is a quarter-inch iron rod, bent as indicated in drawing for accurate fit over shoulders and thighs, and covered with rubber tubing. E is a swivel attachment so that it can be used on either side of frame. H—K is a bar for securing thumb screw D. Canvas is laced on one side to permit smooth surface for ventral position.

# THE END RESULTS OF COXA PLANA

BY ARTHUR T. LEGG, M.D., BOSTON

It is my intention to report the conclusions which I have drawn as to end results in the condition of coxa plana, basing my opinions on a series of forty cases whose duration has been ten years or longer.

In analyzing the terminal results of these forty cases, which include the first five cases of this condition reported by me in 1908, I have been struck by the fact that there are different types of end results, and that they bear a definite relation to the different types of the original pathology. In other words, it is possible to prognosticate the ultimate change in structure, and to some extent the functional disability, at an early stage in the course, although it is my belief that the end result is not obtained in certain cases until the uniting of the epiphysis with the shaft at the age of about eighteen years.

Observers have described the end results in more or less similar terms, giving a general description of limitation of motion in abduction and rota-

FIG. 1

Typical "mushroom type" epiphysis. Slight migration of epiphysis. Slight rounding off of upper angle of neck with slight shortening of neck.

tion, with shortening of the leg, and an x-ray picture of migration of the epiphysis and widening of the neck of the femur.

I find that end results show a marked variation in the amount of limitation of motion, and in the extent of the x-ray changes. The final picture varies with the different types as seen at the onset, as does also the clinical course. The initial picture is important as to the prognosis of ultimate deformity and functional disability.

I described in my original paper two distinct varieties of coxa plana—the mushroom and the cap types. In the mushroom type the head of the femur gives the appearance of the top of a mushroom, while in the cap type, the head, *though flattened*, is not spread out as in the former.

All the cases of the *mushroom* type seen by me have sought advice on account of a limp unaccompanied by pain, and have run an uneventful course; that is, they have experienced no pain or marked spasm, and while the limp has persisted in some, others have shown *no* ultimate limp, and *no* limitation of motion. The shortening in these cases has been less than in the end results of the cap type. About one-half of the cases in this mushroom group have shown no shortening whatever, and none have shown more than one-half inch.

FIG. 2

A "cap type" epiphysis. Early stage. Without fragmentation.

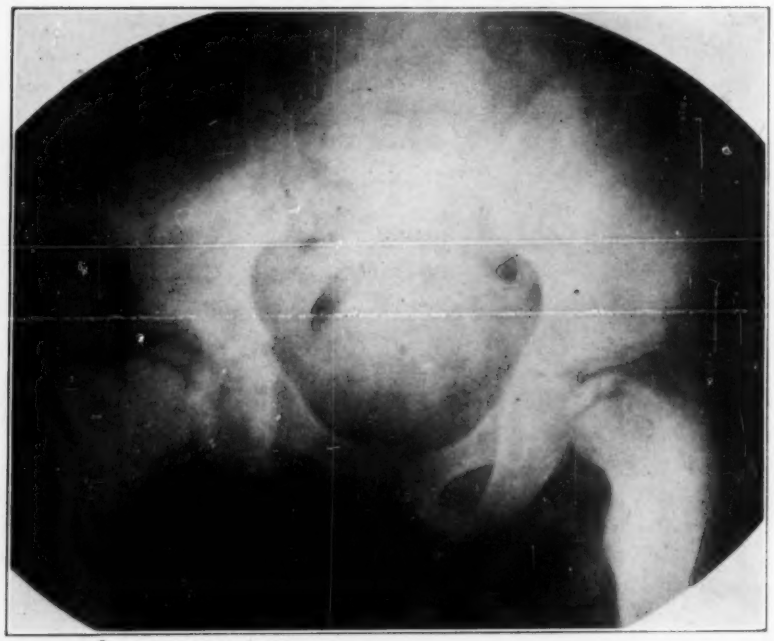


FIG. 3
Double "cap type" epiphysis at early stage. With fragmentation.

FIG. 4
Wedge-shaped epiphysis from subluxation. Not coxa plana.

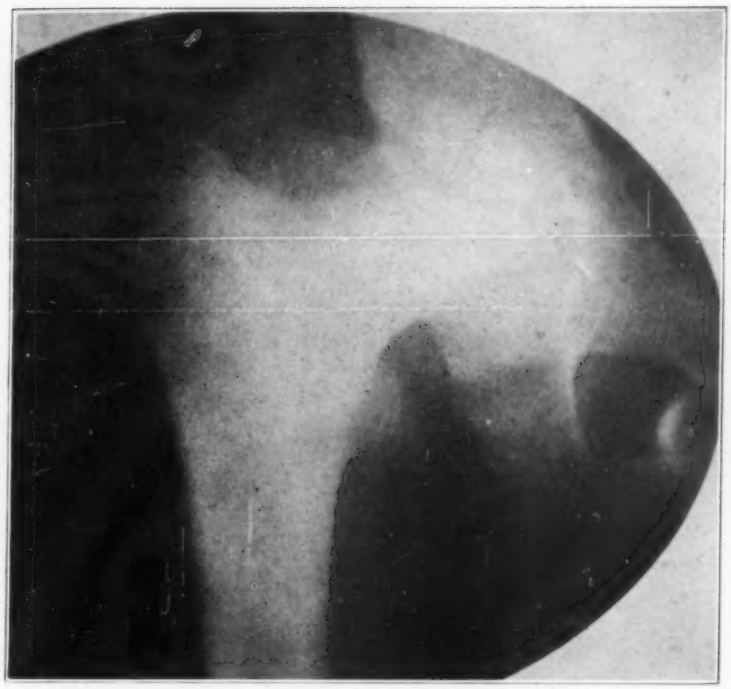


FIG. 5

End result of Fig. 3. Right hip. E. E., male, age 22. Sixteen years since onset. "Cap type." Marked migration of epiphysis and shortening of neck. Abduction and rotation limited. Legs of equal length.

The x-ray appearance at the onset has shown the mushroomed epiphysis with very little or no areas of increased radiability or fragmentation, and a slight rounding off of the upper angle of the neck and some migration of the epiphyseal bone center toward the trochanter. The neck has usually shown some broadening.

The *final* picture of this type shows in some cases very little migration of the epiphysis, while others show migration well out to the great trochanter. It is, of course, the cases with very slight migration of the epiphysis that show no ultimate limitation in abduction and no shortening.

In these cases also, the epiphyseal bone centers do not fragment or show any marked variation in radiability; and the neck, except for the rounding off of its upper angle, is not shortened materially and its radiability is fairly uniform.

The cases of the *cap* type, besides the limp, may complain of some pain, and considerable limitation of motion, and spasm may be present.

The epiphyseal bone center in this class generally fragments, and the diaphysis also will show areas of marked increase in radiability. It is in this class also that the cases may suffer attacks of fairly acute pain and

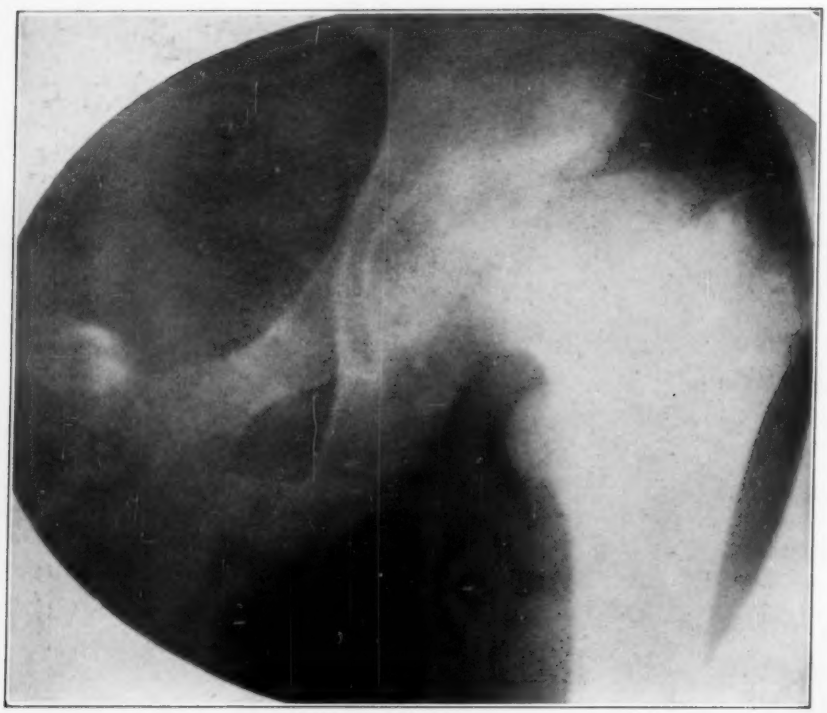


FIG. 6

End result of Fig. 3. Left hip. E. E., male, age 22. Sixteen years after onset. "Cap type." Marked migration of epiphysis and shortening of neck. Abduction and internal rotation limited.

spasm with complete limitation of motion. The ultimate results in these cases show marked shortening of the neck and in some cases, I believe, complete disappearance of the epiphysis.

With the migration of the epiphysis and shortening of the neck seen with this type, we find marked limitation in abduction and obviously greater shortening of the leg. Perfect motion is *never* found as an end result in this type.

The duration of the process differs also with the two groups. The changes taking place in the mushroom type being much less than in the other, the process reaches the final state much sooner.

In the cap type the pathological changes are of much longer duration and I believe the ultimate result is not reached until the epiphysis has become united with the neck.

The cases of coxa plana occurring after congenital dislocation of the hip reduction are similar to the *ordinary* cases. They may be of the mushroom or cap type. The head of the femur may be partially outside the brim of the acetabulum and the neck may show some distortion as ordinarily seen in congenital hip cases.

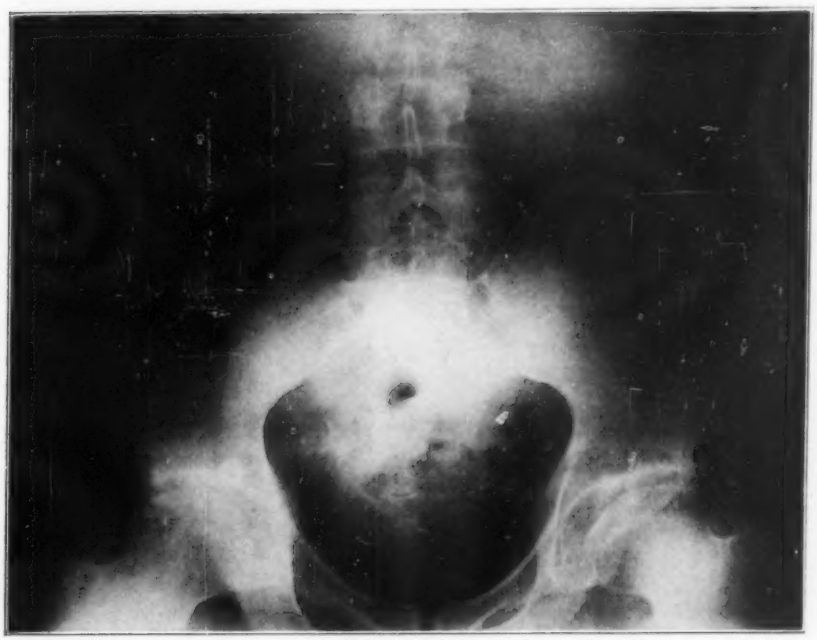


FIG. 7

J. M., male, age 31. Left hip. Twenty-five years after onset. "Mushroom type." Moderate migration of epiphysis. Slight limit in abduction. No shortening. No symptoms. Very slight shortening of neck.

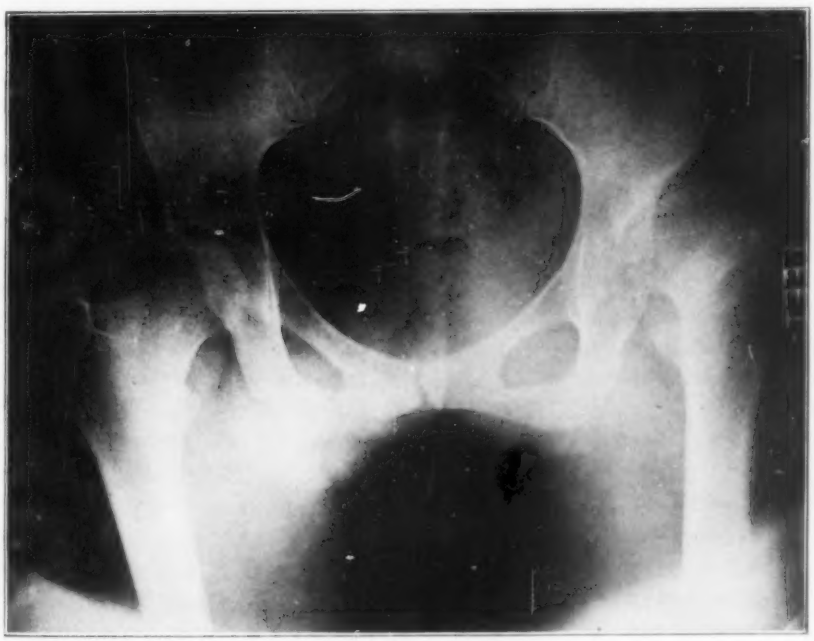


FIG. 8

Male, age 19. Coxa plana following reduction of congenital dislocation of hip (left). "Mushroom type." Moderate migration of epiphysis and shortening of neck. One-half inch shortening. Slight limitation in abduction.

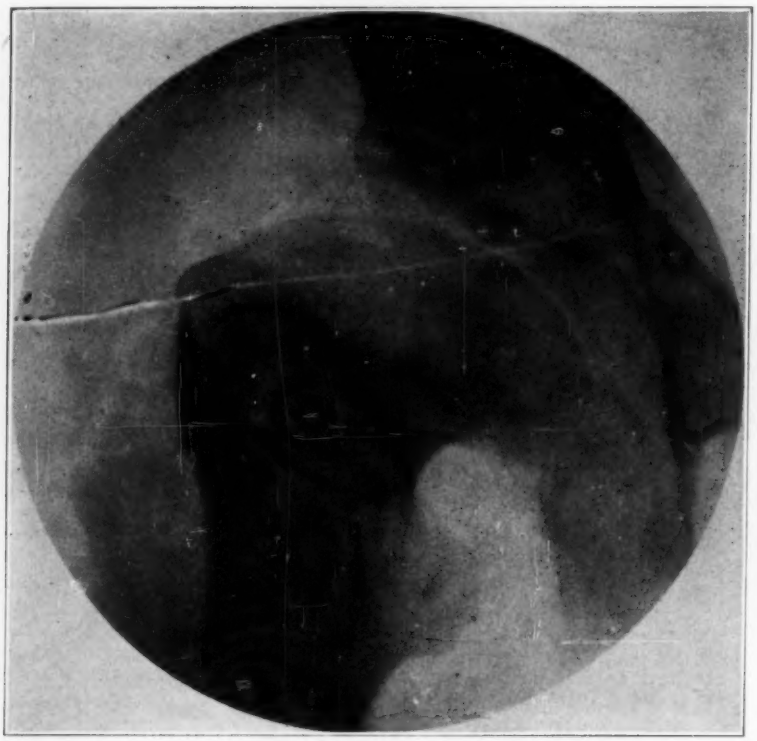


FIG. 9

Male, age 31. End result of old coxa plana found in army. History of limp when a child. Condition recognized from x-ray taken on account of pain following a long hike. By courtesy of Dr. A. W. George, Boston.

The thickening usually felt anterior to the neck persists in the majority of cases after the end result is reached.

The ultimate shortening, as I have said, varies in the two types. From nothing to about one-half an inch in the mushroom group, to one-half to one inch in the cap group. I have seen one case showing one and one-half inches of shortening as the end result of a cap type case without apparent explanation.

It *always* may be said that ultimately the cases of both types will never be incapacitated, although the majority will tire after long standing and walking, or after movements that require extreme abduction, such as riding. Slightly more than half the cases will probably show a persistent limp.

There is considerable discussion in regard to the appropriate treatment for this affection. It must be admitted that while any process which suggests a weakening in bone structure is going on in the hip-joint, it would seem theoretically sound treatment to allow no weight-bearing. It has been my experience, however, that relief from weight-bearing has in

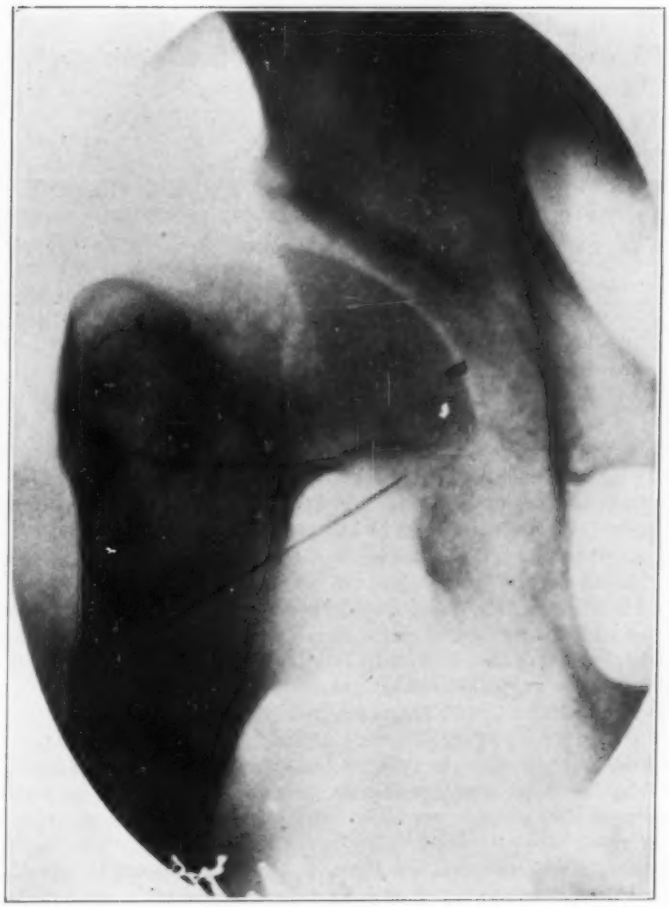


FIG. 10

Male, age 29. End result of old coxa plana found in army. History of limp when a child. Condition recognized from x-ray taken on account of pain following riding a horse. By courtesy of Dr. J. B. Fitts, Richmond, Va.

no way affected the end result, that is, in those cases in which I have not allowed weight-bearing, the end result has not varied in any way from those in which weight-bearing on the affected leg throughout the course of the disease has been allowed.

To summarize my conclusions; the final results seen in coxa plana show a distinct difference in the two types of cases:

1. The mushroom type shows no marked atrophy or fragmentation of the epiphyseal bone centers. The epiphysis may migrate to the great trochanter in some cases; in others it migrates very little. Abduction and, at times, the rotations are limited, when the epiphysis shows marked migration, but if there is very little migration, motion at the hip may be normal in adult life. There is less shortening in this type.

2. The cap type shows marked variation in radiability in the epiphyseal bone center and neck and fragmentation of the epiphyseal bone center and marked shortening and rounding off of the upper angle of the neck. The epiphysis in some cases seems to be obliterated. The ultimate limitation of motion and shortening of the leg are generally considerable.

I believe that early in the course of the condition generally known as coxa plana, we may prognosticate with much assurance what the final limitation of motion and amount of shortening is likely to be, in any given case.

## DISCUSSION

NOTE: The paper of Dr. Philip D. Wilson referred to in the following discussion will appear in a later issue of the *Journal*.

DR. ROBERT B. OSGOOD, Boston, Mass.: These papers are very interesting, Dr. Wilson's bearing so definitely on Dr. Legg's. Obviously the blood supply in connection with these cases is always important. Dr. Legg's paper is the presentation of a very important series of observations which he has made. We must remember that his report of cases preceded everyone else's, though Waldenström in Sweden made a report about the same time as Legg. The name "coxa plana" was introduced by Waldenström. Perthes, in his article in the Archiv für Klinischer Chirurgie in 1910, agrees with Legg that treatment is apparently unimportant. Dr. Legg has confined his paper entirely to end results, but we, as clinicians, must be interested in the etiology. It is obviously unwise for us to draw any conclusions, but I would show you two cases:

(1) A case in the Children's Hospital which just occurred is very interesting to us. It shows the "cap" type and suggests very strongly some focal condition. We obtained permission from the parents to explore the hip. Dr. Legg did so and found an almost normal looking head and acetabular cavity. He tunneled into the area of radiability which appears as a cavity in the x-ray, but obtained no pus and the culture was sterile on all media tried.

(2) Perthes mentions a case similar to the one I am about to report. The boy came under observation in 1901. He had an acute infection of the hip joint at that time. The x-ray showed nothing at all. It looked like a normal hip joint. The surgeon explored the hip, finding very acute infection of the joint and tunneling the neck up to the epiphysis. He found one drop of pus in the neck. The boy ran a very septic course with pus in the urine. He recovered perfectly with no symptoms until five years later, 1906, when he began to have a little limp. The x-ray picture showed a beginning change in the epiphyseal line. We have followed the case and he has had no symptoms except the limp. He is now twenty-eight and served with the French Army during the war. It is quite interesting in relation to Wilson's paper and this paper of Legg's to realize that this tunneling of the neck of the femur to the epiphysis might have interfered with the blood supply. The x-ray taken in 1912 shows changes in the hip joint and a flattening of the epiphyseal bone center. The interesting thing is that he has a shortening of nearly two inches. The shortening was increasing so rapidly that the surgeon thought it was wise to peg the epiphyses at the knee and since then the shortening has remained the same as it was. He now has about two inches of shortening.

It seems to me that the interpretation of these two cases is rather suggestive in relation to trauma and disturbance of the blood supply. These cases, unless followed through carefully, might well have been attributed to some infection or bone focus.

DR. F. C. KIDNER, Detroit, Mich.: Dr. Wilson, in his very interesting, well assembled and well worked out paper, made one point in relation to the circulation as regards the epiphysis. In his slides he showed how the circulation need not be cut off when the central supply is cut, but may go around as it did in his illustration. I had

recently a case of the same thing, where the whole circulation was destroyed. A very severe epiphyseal fracture was reduced and held in a corrected position for five months. It was then gradually allowed out of plaster in a protective splint and was kept protected for a year. At the end of a year weight-bearing was allowed, and a complete displacement recurred within two weeks. I believe that here the injury had been so complete that the blood vessels had been ruptured and torn away and that the nutrition of the head thereafter was so bad that even the long period of one year was not sufficient to restore it.

Dr. Legg's paper is also very interesting. I am afraid I shall have to give up my theory of direct infection as the cause of his disease. I do feel even yet that the explanation of traumatic and congenital disturbances is not sufficient. I have now examined material from four of these cases. In all the cases the pathologic reports have shown a real inflammatory reaction as we see it with round-cell infiltration and bone destruction and bone proliferation. I am going to show a series of pictures of one case which is an interesting example of the difficulty of differential diagnosis between this disease and tuberculosis. I believe that none of us can be sure in what Dr. Legg calls the "cap" type of Legg's disease, whether we have tuberculosis or Legg's disease. It is often necessary to remove a specimen in order to establish the diagnosis.

The first picture was taken two and one-half years ago when the disease was first discovered. I think it is a fair example of the cap type. There was so much destruction, however, that I did not feel justified in assuming that it was Legg's disease. I removed a small section, cutting longitudinally, not because of the circulation, but because it was convenient to get at it in that way. The sections pathologically showed no tuberculosis but a combination of bone destruction and bone proliferation, with a considerable degree of round-cell infiltration. The cultures were absolutely sterile.

The next picture shows the small piece from which the section was cut. We see in the picture taken some six months later a very marked restoration of the calcium salts through the neck. The head, however, is not so solidly marked out. There is not much calcium in it. It has become a little more ragged. Some trace of filling in with bone cells is continuing and the head is spread out a little more than it was originally. The same process continued and the fragmentation became worse. Here again the neck has become almost solid and the head has flattened down and more calcium cells are appearing.

Here we have the final picture taken last month which shows an almost complete restoration of the head and neck. It is flattened, to be sure. The neck is thicker and wider. The calcium is almost replaced and there is very little depression of the head. There is only one-half inch of shortening.

I do not agree with Dr. Legg that protection is not necessary. These hips should be kept free of weight-bearing for a very long period of time. If they are so held long enough, they will show far better results and less shortening than if the patients are allowed to walk.

Dr. E. W. Ryerson, Chicago, Ill.: When one sees the pictures of the old cases, several examples of which Dr. Legg has shown on the film, it seems to me difficult to understand his views as to the inefficacy of treatment. I have seen a great many such cases, evidently old, healed Legg's disease, in which the neck of the femur had become broad and short, and but little of the head remained. All of these cases had received no treatment whatever. I have seen many others which were properly treated and in which very little deformity occurred.

A few words as to treatment. Plaster-of-Paris fixation should not be used. I personally believe that encasement in plaster-of-Paris actually produces bone atrophy, and definitely delays healing. Weight-bearing should not be permitted, in cases of Legg's disease, because the femoral head is softened and will become flattened if allowed to press against the acetabulum. The proper treatment, in my opinion, is the use of the Thomas caliper splint, continued until ossification is complete as shown by x-ray pictures; some cases require two or three years, and some only a few months. I do

not think they should be left untreated, and I do not think they should be treated by plaster-of-Paris. I think, as Dr. Kidner does, that they should be treated by relief from weight-bearing until relief is no longer necessary.

Dr. W. S. Baer, Baltimore, Md.: I do not wish to let this opportunity pass without expressing to Dr. Wilson our appreciation of his beautiful piece of work, beautifully conceived and more beautifully carried out. He confirms the observation that there is no direct connection between the epiphyses of bones and joints and the diaphysis of the neck. He brings out a true clinical point that infection in the epiphysis is not carried into the diaphysis and diaphyseal infection is not carried to the epiphysis unless we, as surgeons, carry it there. Consequently we should be very careful how we operate on these cases because infection is more or less self-limited if we are not making destruction.

In regard to Dr. Legg's paper, a very beautiful one, I would like to ask him if he has ever taken into consideration the relation of osteo-arthritis of the hip and coxa plana. The etiology of osteo-arthritis of the hip has never been clear in my mind. I wonder if osteo-arthritis of the hip joint may not be a later stage of these cases.

In regard to Dr. Kidner's observation that we should make a direct exploratory operation to ascertain the difference between tuberculosis and an infectious process, I can not quite agree. I think it is quite serious to go into the joint itself, particularly the epiphysis, and make a diagnosis. Personally I would suggest that we use more continuously than most of us do the reaction of tuberculin as a diagnostic test for tuberculosis. I think it gives us more information in regard to tuberculosis than any other agent we have and particularly as we can use it with very little risk.

Dr. Willis C. Campbell, Memphis, Tenn.: The mushroom heads as demonstrated by Dr. Wilson are also frequently caused by acute infection, and cannot be attributed in all cases to Legg's disease.

In our discussions we should also give due credit to Dr. Arthur T. Legg, who first described coxa plana.

Dr. A. T. Legg, Boston, Mass. (closing his part of the discussion): I should like to say in regard to the treatment of these cases that of the original cases that were reported in 1908 there were two of the cap type. Those were considered tuberculosis at that time and they were treated as tuberculosis with a traction splint for five years. Of course, those showed ultimately a marked shortening of the neck and marked atrophy of the epiphysis. In those cases relief from weight-bearing did not stop the process from going on and it was kept up for five years.

In regard to Dr. Baer's remarks, I have not tested them at all.

Dr. Campbell just mentioned that it should be called Legg's disease. It seems to me it should be called coxa plana and not Legg's disease.

# STUDIES ON THE BLOOD CALCIUM AND PHOSPHORUS IN ARTHRITIS*

BY I. WM. NACHLAS, M.D., BALTIMORE, MD.

It has been recognized by those who see large numbers of arthritics that there is one group of patients particularly characterized by bony overgrowth about the joints. So pronounced is this tendency that many authorities have been led to believe that this excessive deposition of bone is a local manifestation of a general metabolic disturbance. Since bony matter consists in great part of calcium phosphate, can one find an anomaly in the calcium or phosphorus content of the blood in patients suffering with this disease?

Another group of arthritics is clinically characterized by pathology which is essentially limited to the soft parts. Will this group, with its relative freedom from new bone formation, show a calcium and phosphorus content that resembles the normal? Furthermore, can one establish a difference in the blood content of these elements in the two types of arthritis mentioned?

Obviously a positive distinction such as this would be of great value, not only because it assists in further classifying our rheumatoid conditions, but particularly because it offers a lead to the study of etiological factors.

For working purposes we shall accept the classification made by R. Llewellyn Jones in his book on "Arthritis Deformans". He subdivides the arthritis deformans group into—first, the rheumatoid arthritis, and, second, the osteo-arthritis[1].

Pathologically, in the first group, the morbid changes occur primarily in the softer structures, the periarticular and synovial tissues undergoing thickening, with hypertrophy of the synovial fringes, while ultimately a process of atrophy takes place, involving all the constituent elements of the joints, including the bony and cartilaginous as well as the softer tissues.

In osteo-arthritis the primary changes take place in the cartilaginous and bony structures, which undergo enlargement or hypertrophy, with the formation of osteophytic outgrowths, thus contrasting sharply with the essential atrophic process characteristic of the first-named group, in which, if new bony formation occurs, it takes place secondarily, and is inconsiderable in amount.

The general problem of bone production has long been a matter of interest to investigators. Morphologically, bone production can be considered under two heads, (1) ossification, the physiological formation of bony tissue, and, (2) calcification, the pathological deposition of bone[2]. The two processes lend themselves to microscopic differentiation. Ossification

*Submitted to Membership Committee on January 22, 1926, as a thesis for membership in American Orthopaedic Association.

occurs only in connective tissue; calcification can take place in any type of tissue. In ossification there is a solidification of a previously prepared homogeneous ground substance, while in calcification one finds deposition of spheroids of bone, calcospherites, which may or may not fuse together. Chemically, however, no distinction can be made. Wells has shown that the inorganic constituents of both types of bone have the same chemical analysis, so that as far as our present problem is concerned no distinction need be made in the forms of the arthritic exostoses.

The chemical structure of the inorganic content of bone has been fairly well established. Analysis yields Ca, $PO_4$, $CO_3$, Mg, and a small amount of the more soluble salts. Of these, calcium and phosphate are by far the most predominant and are found in the ratio necessary for the salt $Ca_3(PO_4)_2$. This salt constitutes about eighty-five per cent. of the bony inorganic salts. According to Berzelius[3], the composition of bone is as follows:

| | | |
|---|---|---|
| Organic Matter | Gelatin and blood vessels | 33.30 |
| Inorganic Matter | Calcium phosphate | 51.04 |
| | Calcium carbonate | 11.30 |
| | Calcium fluoride | 2.00 |
| | Magnesium phosphate | 1.16 |
| | Sodium oxide and chloride | 1.20 |
| | | 100.00 |

The overwhelming predominance of $Ca_3(PO_4)_2$ in bone leads us to consider the rôle played by calcium and phosphorus in osteogenesis. Calcium is ingested in many ways—in organic form through milk, egg yolk, and cereals, and in inorganic form chiefly through drinking water. The amount of Ca taken up by the blood will vary within narrow limits in accordance with the amount ingested. Excessive calcium is disposed of by the urine and stools. On the other hand, a diminution in the amount of calcium taken in the diet causes a reduction in the amount carried by the blood. The minimum amount of lime by which a Ca equilibrium can be maintained is stated at from 1 to 1½ gms. per diem for the average adult. The amount of Ca absorbed from a given diet will also vary with the concomitant ingestion of phosphates[4]. Numerous investigators have shown that when an excess of phosphates is taken by mouth there is an impairment of the Ca metabolism. On the other hand, the absorption of phosphates is likewise impaired by a diet excessive in calcium[5].

The relationship of calcium and phosphorus to bone pathology has been pointed to by earlier investigators. Thus in osteomalacia it is claimed that more calcium is excreted by the body than is taken in. In cases of hunger, Wellman found that more salt was lost than the metabolism of the fleshy parts could account for. Since the principal excess was phosphoric pentoxide and calcium and magnesium oxide in about the same proportion as in bone, he attributed this to change in the skeletal system.

Furthermore, the skeletons of the starved animals showed an actual loss of six or seven per cent. of their weight. In myositis ossificans the amount of calcium excreted in the urine is said to be lower than normal[4].

More recent studies, particularly those of McCollum, et al.[6], have established the dependence of bone formation on diet. In a remarkable series of experiments, they have shown that in growing rats the deposition of lime salts ceases when the P falls below a certain level. On the other hand, when in animals whose tissues lack the normal bony deposits, the diet is changed so as to include a larger amount of the deficient elements, there is a restoration of the bony structure to the normal.

Since the blood is presumably the medium for transportation of calcium and phosphorus to the bony tissues, analytical studies were made of the normal content of these elements in normal blood. By microchemical methods it has been possible to establish the level of the elements as 9.5 to 10.5 mgms. of Ca and 3 to 4 mgms. of phosphorus to the 100 cc. of blood in the normal adult[7]. In childhood there is a slight increase in the amount of phosphorus, 4.5 to 6 mgms. Practically all of the Ca is limited to the serum, the blood cells containing an insignificant amount of this element[8]. Phosphorus, however, is found in both the cellular and serum elements of the blood. Since the serum offers the medium for chemical exchange, only the serum phosphorus was studied. The method used determines the inorganic phosphorus, the amount of undetermined P that remains being sufficiently small to make it negligible.

Applying these facts to the study of rickets in children, Howland and Kramer have made some interesting observations[9]. Rickets is a disease of children, characterized by a failure of the lime salts to deposit in the growing bone. Examining the blood in rachitic children, the investigators have shown that there exists a diminution in the P content of the serum, while the Ca is essentially normal or only slightly below normal. At first sight, this observation would seem to controvert all of the preconceived notions that the *calcium* content of the blood determines bone deposition. On the other hand, application of the principle of the chemical equilibrium constant gives an explanation for this apparent discrepancy, and at the same time gives us a more thorough understanding of the processes of bone precipitation.

It is known as a general principle that the rate of chemical combination of two substances will be in direct relation to the *product* of the molecular concentration of each ingredient, represented in the formula below as C and $C_2$ respectively, and in inverse relation to the molecular concentration of the substance formed, $C_3$. Mathematically this is expressed as

$$\frac{C_1 \times C_2}{C_3} = K$$

Since the solubility of $Ca_3 (PO_4)_2$ is negligible, for practical purposes, we may say that the precipitation of bone will vary with the *product* of the calcium and phosphorus contents.

In the study of non-union of fractures, Petersen[10] has likewise offered interesting observations. The usual case of fracture examined by him has shown a definite rise in the calcium-phosphorus product during the healing stage. On the other hand, in those cases where non-union takes place (mechanical factors having been excluded), there is a reduction in this product. When the figure is below 30, the bones do not unite. Between 30 and 35 there is little healing, but between 35 and 40 the bone-repair is active.

Calcification can take place in vitro[11], without the presence of body fluids. Shipley, Kramer and Howland[12] have conclusively shown that bone deposition will take place in sections of osteoid tissue immersed in an aqueous solution of the inorganic salts found in serum in which the calcium-phosphorus product is satisfactory. In a series of experiments, they have shown that the process of calcification is the same in vitro as in vivo, that it depends on the product of calcium and phosphorus, and that it will occur within a wide range of reaction, from pH 7.05 to 7.50. Subsequent work has led them to the conclusion that the readings Ca x P are more valuable indicators of the conditions necessary for calcification than the product readings of the ionized calcium and ionized phosphates, i.e., $[Ca^{+++}]3 \times (PO_4^{\equiv})2$, as suggested by Holt[13].

Why does this chemical combination that produces bone occur in only definite localized areas? What are the factors that determine the localization of these deposits? Various theories have been advanced to explain the *selective* deposition of lime salts. One theory claims that the local excretion of acids causes a local alkalinity that results in a precipitation of calcium salts. That local acidosis can occur is substantiated by the recent work by Rous and Drury[14]. Another theory, based on Barillé's belief that the calcium is present in the form of tribasic calcium-carbono-phosphate, suggests that the $CO_2$ concentration of the blood at these points is reduced[2].

Still another theory is offered that the local utilization of the protein radical of the calcium-protein molecule leaves the calcium free. A fourth theory suggests the formation of a ground substance having a special affinity for calcium. Watt[15] comes to the conclusion that the bone formation is the result of a combination of precipitation and secretion.

The work of Shipley, Kramer, and Howland has thrown much light on this problem and offers to lead to a solution. In rachitic bone they have shown that calcification is limited to the provisional zone, and here the deposit is between the cells and not within them. Furthermore, in the process of calcification it is essential that the cells be vital, since cells injured by boiling or by immersion in a poison such as cyanide or toluol will prevent the bony deposition. These findings are presented as facts, without any suggested explanation of the cellular activity that affects the solution.

One is, however, safe in saying that the serum content of calcium and phosphorus is closely related to the process of calcification, and that their value in bone deposition is more accurately registered by their product, Ca x P, than by the individual readings.

A survey of the literature indicates that the idea that the metabolism of the inorganic salts may be faulty in arthritics is not new. Friedenwald and Ruhrah[4] state that there is a retention of lime salts in arthritis deformans. Pemberton[16, 17], in 1923, made a study of ten patients suffering with arthritis, to determine the blood calcium. His determinations were made as general observations on arthritic patients without any effort to correlate the chemical findings with the amount of bony change shown by his patients. In his tables the only descriptions of his arthritic patients are: severe, 5 cases; moderate, 3 cases; convalescent and improving, 2 cases. His determinations are remarkably uniform, ranging between 7.1 and 7.3 milligrams per 100 cc. of blood. In all but one case, for which the rating was 6.5, no relationship could be established between the severity of the disease and the calcium content. No study of the phosphorus content of these patients is recorded, though it is suggested elsewhere that $P_2O_5$ plays a rôle in arthritis[16]. The striking difference between his normal reading and those which have since been determined as normal can probably be attributed to a difference in technique.

Later, Weil and Guillaumin[18], working on the proposition that the bony overgrowth in patients suffering with chronic rheumatism may be associated with hypercalcemia, studied the calcium and magnesium in twelve cases. These patients, as reported by them, are not classified in accordance with the amount of bony overgrowth. The only descriptions offered are "general chronic ankylosing rheumatism", "general deforming rheumatism", "chronic ankle rheumatism", etc. Their results differ from Pemberton's in that they find a definite calcium increase in several of their cases. They note, however, that the hypercalcemia is not constant in all their cases and offer the conclusion that the blood calcium and magnesium in arthritics is sometimes, but not necessarily always, increased. No examination for the phosphorus content is reported. Since their findings are so intimately related to our present problem, their table is included.

| | *Ca* | *Mg.* |
|---|---|---|
| General Chronic Ankylosing Rheumatism | 17.8 | 3.5 |
| General Chronic Deforming Rheumatism | 17.8 | 3.1 |
| Chronic Rheumatism of knees | 14.9 | 3.3 |
| General Chronic Ankylosing Rheumatism | 17.6 | 2.9 |
| Chronic Rheumatism of wrist | 14.7 | 2.2 |
| General Chronic Ankylosing Rheumatism | 14.2 | 3.0 |
| Chronic General Rheumatism of Thyro-ovarian type | 13.5 | 2.9 |
| Chronic Shoulder Rheumatism | 11.6 | 2.09 |
| Chronic Ankle Rheumatism | 11.5 | 1.6 |
| Chronic General Deforming Rheumatism | 11.4 | 2.1 |
| Chronic General Rheumatism of Thyro-ovarian type | 11.1 | 2.7 |

It should be noted that their technique for calcium determination was not unlike the one we used. It is described as follows: The serum, after separation from the cells by centrifugalization, was treated with trichloracetic acid and filtered. The filtrate was then treated with oxalic acid, and

the oxalate measured by permanganate titration. It is also noteworthy that their figures for the normal individual are recorded in another paper as calcium 10 to 12 milligrams per 100 cc., figures that are quite similar to those that we have accepted as our normal[19].

In The Journal of Metabolic Research for 1924, Robert Mark[20] reports "Some Observations on Arthritis Deformans and Calcium Metabolism". His determinations were made on whole blood by G. W. Clarke's method. With this technique he finds the normal calcium content of the whole blood to lie between 10 and 12. In one case of "typical advanced arthritis deformans" he finds a total blood calcium of 20.35 per cent. In another patient, seventy-one years old, with an arthritis of fifteen years' standing, with involvement consisting of swollen, deformed, and painful elbows, wrists, fingers, and knees, the calcium was 18.51 per cent. A third case, a fifty-seven year old woman, described as a chronic polyarthritis that would fit into our rheumatoid class, was studied more intensively. Laboratory tests showed

| | |
|---|---|
| Plasma blood phosphates | 4.1 mgms. |
| Blood sugar | 131. " |
| Blood chlorides | 614. " |
| Blood urea | 20. " |
| Blood creatinin | 2. " |
| Carbon dioxide combining power | 48.4 c.c. |
| Blood calcium | 27.4 mgms. |

After insulin administration no change in the calcium content was noted. On a calcium-poor diet the blood calcium diminished to 17.6. Following HCl administration the calcium rose to 19.7. Oral alkalies made no change. The same was true of sodium salicylate medication. The fourth case, one of acute articular rheumatism, is reported as having a blood calcium of 10.95 per cent.

Obviously, there is considerable discrepancy in the conclusions reached by these authors. It is noted that these conclusions are based on the determinations of calcium alone, not on the Ca x P product, and that no attempt was made to correlate their findings with the amount of bone production. It is also questionable if the methods used in their determinations were universally reliable. Finally, the conclusions are based on only small groups of cases, the largest group comprising but twelve observations.

In this paper our observations are based on a study of thirty-seven patients. Our examinations have been restricted to adults, to obviate the necessity of using more than one standard for comparison, the normal level in children being different from the normal level in adults. The group includes both male and female, white and colored patients.

The procedure we employed follows: A careful history was taken of our patients, with particular reference to the duration of the disease, the number of joints involved, and the severity of the arthritic pain. A clinical examination was then made and the patient classified in the osteo-

OSTEO-ARTHRITIS

| *Name* | *Age* | *Sex* | *Color* | *Ca* | *P* | *Product* | *Activity* | *Bony Overgrowth* |
|---|---|---|---|---|---|---|---|---|
| J.S. | 71 | M | W | 10. | 3 | 30 | ++ | ++ |
| K.W. | 48 | F | W | 10.6 | 3.2 | 33.92 | ++ | ++ |
| C.B. | 70 | M | C | 10.4 | 3. | 31.2 | ++ | +++ |
| A.S. | 63 | F | W | 9.2 | 3. | 27.6 | ++ | ++ |
| L.G. | 68 | F | W | 10.36 | .. | .... | +++ | ++ |
| D.E. | 63 | F | W | 10.6 | 3.4 | 36.04 | +++ | +++ |
| J.G. | 66 | F | W | 11. | 2.6 | 28.6 | +++ | +++ |
| D.K. | 58 | F | W | 9.98 | 4. | 39.92 | +++ | +++ |
| M.S. | 50 | F | W | 11.6 | 3.3 | 38.28 | + | ++ |
| A.L. | 65 | M | W | .... | 3.2 | .... | +++ | +++ |
| B.D. | 62 | F | W | 10.2 | .. | .... | ++ | ++ |
| A.K. | 54 | M | W | 12.5 | 3.3 | 41.25 | ++ | + |
| M.C. | 59 | M | W | ... | 3 | .... | ++ | +++ |
| R.A. | 55 | F | W | 10.6 | 3.3 | 34.98 | ++ | ++ |
| J.G. | 49 | M | W | 11.4 | 3 | 34.2 | ++ | ++ |
| E.E. | 60 | F | W | .... | 3 | .... | + | ++ |
| W.P. | 51 | M | W | .... | 3.3 | .... | + | ++ |
| F.C. | 62 | M | W | 11.2 | 2.5 | 28 | + | ++ |
| R.D. | 49 | F | C | 10.8 | 3. | 32.4 | ++ | ++ |

arthritic or rheumatoid group. Care was taken to exclude the monarticular arthritic who could trace the onset of his trouble to a major joint injury. X-ray examinations were then made and studied particularly with reference to the amount of demonstrable bony overgrowth.

Blood examinations were generally made within a few days after the patient presented himself to us for treatment. In all of the patients here reported sufficient blood was taken to permit calcium and phosphorus examinations on the same specimen so that our readings represent the relationship of these elements as well as their individual figures. On a number of our patients we have made other chemical analyses such as blood-sugar, creatinin, urea, but since these figures showed nothing new and since we did not do this uniformly in all of our cases we have not included them in our present report.

For the calcium determination we have used the method devised by Kramer and Tisdall[21]; for phosphorus that of Briggs' modification of the Bell-Doisy method[22]. The blood, having been taken in syringes and collected in test tubes carefully dried to avoid haemolysis, was centrifuged shortly after removal from the body at a rate (1800 revolutions per minute) calculated to separate the cells without breaking them. The serum was then drawn off and used for the examinations.

In the calcium determination, ammonium oxalate was added to the serum to precipitate the Ca as calcium oxalate. This was washed with ammonium hydrate, dissolved in sulphuric acid and titrated with potassium permanganate to a pink color which persisted for one minute. In the phosphorus determination, the protein was precipitated by trichloracetic acid and filtered off. To the filtrate was added a solution of ammonium molybdate in sulphuric acid, sodium sulphite and hydroquinone. Using a colorimeter we made readings against a known standard.

We have tabulated our figures so as to indicate the age, sex, and color of the patient, the clinical activity of the disease process, the bony over-

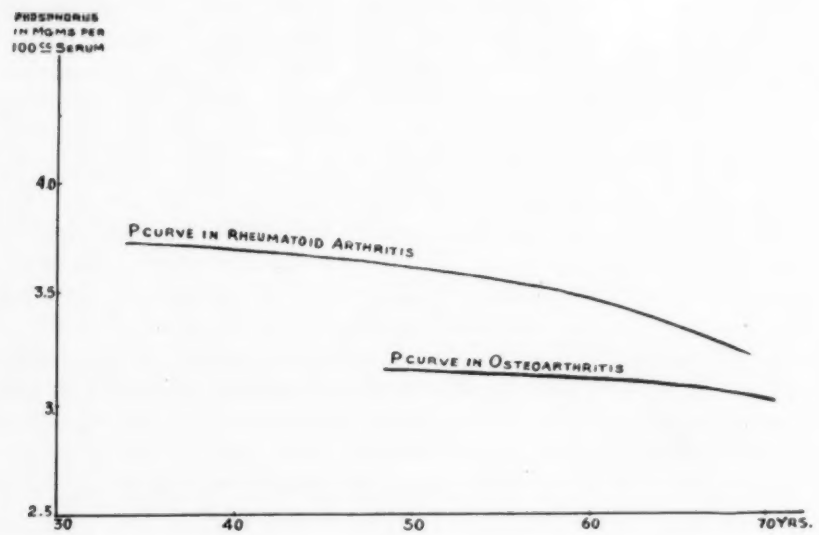
RHEUMATOID (OR ATROPHIC) ARTHRITIS

| *Name* | *Age* | *Sex* | *Color* | *Ca* | *P* | *Product* | *Activity* | *Bony Overgrowth* |
|---|---|---|---|---|---|---|---|---|
| J.D. | 42 | M | W | 11.8 | 3.5 | 41.30 | ++++ | + |
| R.F. | 68 | F | W | 11.8 | 2.7 | 31.86 | ++++ | + |
| H.S. | 49 | M | W | 9.9 | 3.7 | 36.63 | +++ | ○ |
| J.P. | 44 | M | W | 9. | 4. | 36. | ++ | ○ |
| G.J. | 48 | F | W | .... | 3.1 | .... | +++ | + |
| A.S. | 60 | M | W | 11. | 3.8 | 41.8 | ++ | + |
| K.F. | 42 | F | W | 9.7 | 3.7 | 35.89 | ++ | ○ |
| M.B. | 59 | M | W | 11.3 | 3.5 | 39.55 | +++ | ○ |
| M.S. | 42 | M | W | 11.4 | 3.1 | 35.34 | ++ | ○ |
| H.K. | 34 | M | W | 11.0 | 4.2 | 46.2 | +++ | ○ |
| M.W. | 45 | F | W | 11.0 | 3.5 | 38.5 | ++ | ○ |
| H.W. | 65 | F | W | 10.4 | 3.3 | 34.32 | ++ | ○ |
| S.N. | 48 | F | C | 10.4 | 3.1 | 32.24 | ++ | + |
| C.S. | 53 | F | W | 9.6 | 3.8 | 36.48 | +++ | + |
| H.K. | 47 | F | W | 10.3 | 3.6 | 37.08 | +++ | + |
| F.O. | 55 | F | W | 10.6 | 3.7 | 39.22 | + | + |
| A.B. | 48 | F | W | 11.7 | 3. | 35.1 | +++ | + |
| A.H. | 53 | M | W | 11.2 | 4.1 | 45.92 | + | +++ |

growth as indicated by x-ray, the calcium and the phosphorus in milligrams per 100 cc. of serum, and the Ca x P product.

In our osteo-arthritic group all of our patients are over forty-nine years of age. This fits in with the general impression that osteo-arthritis is essentially a disease of the later years of life. It will be noted that the calcium readings cover a rather wide range, from 9.2 to 12.5. If we should exclude the one lowest and the one highest reading as the result of possible error in technique, we find that all of our figures lie between 9.98 and 11.6, readings which are undoubtedly within normal limits. We can therefore say that in our cases the calcium readings in osteo-arthritis do not differ from those in normal patients.

In the rheumatoid group, the ages vary from thirty-four to sixty-eight years. Our lowest calcium reading for these patients is 9, while our



highest is 11.8. These figures likewise show no abnormality when compared to normals. Furthermore, they show no essential difference when compared to those in the osteo-arthritic group.

The phosphorus readings in the two groups lie within normal limits, the osteo-arthritics (with two exceptions) between 3 and 4, and the rheumatoid arthritics (with one exception) between 3 and 4.2. It would therefore be very difficult to distinguish any one case of arthritis from a normal individual by determining the phosphorus content. It is, however, noteworthy that the mean reading is lower in the osteo-arthritics than the mean reading of the rheumatoids. Analysis of the figures in both groups shows that age is a factor that must be considered, i.e., the older the patient, the lower the phosphorus content is likely to be. (See graph). But even if allowance is made for the differences in age, one still finds a lower level in the osteo-arthritics. The difference is slight, but seems to be fairly consistent. It is hoped that by the refinement of technique and the cumulation of large numbers of readings, more value may be assigned to this finding.

The calcium-phosphorus product likewise fails to give us any distinct aberration from the normal or any characteristic distinction between the two groups. In both tables the figures lie chiefly between 30 and 40, and in both the range is equally well covered.

A study of the clinical activity in relation to the figures obtained for the calcium, phosphorus, or calcium-phosphorus determinations does not reveal any concomitant variation. It is, of course, to be noted that the records of the activity of the disease are expressed only as estimates and therefore lack the exactness of the other figures. The same criticism holds true for our method of recording the bony overgrowth as shown by the x-ray. These observations likewise cannot be in any way correlated with the chemical findings. We can, therefore, say that as far as we can determine from our studies, the blood calcium and phosphorus offer no indication of the severity of an arthritic process, whether this arthritic process be judged by the clinical symptoms or by the bony overgrowth.

## CONCLUSIONS

We have been unable to verify the observations of earlier writers that there is an abnormality of the calcium metabolism in arthritis deformans. We have found no abnormality in the serum content of either the calcium phosphorus, or the calcium-phosphorus product in arthritics as compared with normal adults. Furthermore, no reliable distinction is offered by these analyses for the separation of rheumatoid arthritis from osteo-arthritis, the only difference noted by us consisting of a tendency of the phosphorus readings of the osteo-arthritic group to be lower than those of the rheumatoid group. Finally, our observations would show that the activity of the disease, whether measured by the clinical symptoms or by the objective bony overgrowth, is in no way indicated by the results of these analyses.

## BIBLIOGRAPHY


1. Jones, R. Llewellyn: Arthritis Deformans, Bristol, John Wright & Sons, Ltd., 32, 1909.
2. Wells, H. G.: Chemical Pathology, Ed. 4, Philadelphia, W. B. Saunders Co., Chap. XVII, 1920.
3. Berzelius, quoted in Piersol's Human Anatomy, Ed. 7, Philadelphia, J. B. Lippincott Co., I, 84, 1919.
4. Friedenwald, Julius, and Ruhräh, John: Diet in Health and Disease, Ed. 4, Philadelphia, W. B. Saunders Co., 154–155, 1913.
5. Orr, W. J., Holt, L. E., Jr., Wilkins, L., and Boone, F. H.: Am. J. Dis. Child., XXVIII, 574, 1924.
6. McCollum, E. V., Simmonds, N., Shipley, P. G., and Park, E. A.: J. Biol. Chem., XLVII, 507, 1921.
7. Kramer, B., Tisdall, F. F., Howland, J.: Am. J. Dis. Child., XXII, 560, 1921.
8. Kramer, B., and Tisdall, F. F.: J. Biol. Chem., LIII, 241, 1922.
9. Howland, J., and Kramer, B.: Monatschrift fur Kinderheilkunde, XXV, 279, 1923.
10. Petersen, H. A.: J. Bone and Joint Surg., VI, 885, Oct. 1924.
11. Shipley, P. G.: Johns Hopkins Hosp. Bull., XXXV, 304, Sept. 1924.
12. Shipley, P. G.: Kramer, B., and Howland, J.: Am. J. Dis. Child., XXX, 37, 1925.
13. Holt, L. E., Jr.: J. Biol. Chem., LXIV, 579, 1925.
14. Rous, Peyton and Drury, D. R.: J. Am. Med. Assn., LXXXV, 33, July 4, 1925.
15. Watt, J. C.: Arch. Surg., X, 983, 1925.
16. Pemberton, R.: Am. J. Med. Sc., CLXVI, 833, 1923.
17. Pemberton, R., and Foster, G. L.: Arch. Int. Med., XXV, 243, 1920.
18. Weil, M. P., et Guillaumin, C. O.: Compt. rend. Soc. de biol., LXXXVIII, 734, 1923.
19. Weil, M. P., Guillaumin, C. O., et Weismann-Netter, R.: Compt. rend. Soc. de biol., LXXXVIII, 733, 1923.
20. Mark, Robert: J. Metab. Research, IV, 135, 1923.
21. Kramer, B., and Tisdall, F. F.: J. Biol. Chem., XLVII, 475, 1921.
22. Briggs, A. P.: J. Biol. Chem., LIII, 13, 1922.

# THE LATE REPAIR OF FRACTURES OF THE PATELLA AND OF RUPTURE OF THE LIGAMENTUM PATELLAE AND QUADRICEPS TENDON

BY W. E. GALLIE, M.D., AND A. B. LEMESURIER, M.B., TORONTO, CANADA

Rupture of the structures which compose the tendon of the extensor muscle of the knee is a comparatively common injury and one which frequently leads to severe disability. This disability consists of lack of power to extend the knee, with the consequent diminution of strength of the limb in climbing and of stability in ordinary level walking. It results from failure to secure perfect apposition of the ruptured tendons or bone or from subsequent stretching of the scar by which the repair is primarily accomplished. While many patients suffering from defective repair of this injury walk extraordinarily well on level ground, they are barred from all participation in athletic exercises and are disabled completely from returning to occupations which involve climbing or heavy lifting.

There are, of course, all degrees of disability to be found among these patients, depending largely on the degree of separation that has occurred at the line of healing. For example, it is common to see people with ununited fracture of the patella in whom the fibrous union is close and strong, who are conscious of very little weakness of the knee and who, therefore, are not in need of treatment. More frequently, however, the fibrous tissue between the fragments slowly stretches and as a result the patient loses the power of complete extension of the knee and develops a greater or smaller degree of uncontrolled motion. This loss of power to extend the knee may increase until voluntary extension completely disappears.

Similarly, after rupture of the quadriceps tendon above the patella or of the ligamentum patellae, the ability of the patient to extend the knee varies with the perfection of the healing that has occurred. If the scar is strong and if no retraction has taken place, the extensor power will be normal. But, if the scar is weak and the muscle has retracted, in just this proportion will the patient be unable to complete the extension of the knee. When yielding of the scar has once begun, these patients usually get steadily worse until all extensor power has disappeared. This sequence of events is particularly likely to occur in injuries of the patellar ligament, quite irrespective of whether the severed tendon was sutured or not, as the degree of strain to which this small tendon is subjected is so tremendous that no ordinary scar can be expected to withstand it.

## RUPTURE OF THE PATELLAR LIGAMENT

Rupture of the ligamentum patellae is an injury which is not uncommon. It may be produced by indirect violence, much as fracture of the

patella usually occurs, or it may result from violence applied directly to the tense tendon either by some cutting instrument or by some object which is not sufficiently sharp-edged to break the skin. The rupture may occur as a tearing away of the tendon from its origin in the patella or its insertion into the tuberosity of the tibia, or it may occur at any point in the ligament itself. The nature of the injury is demonstrated at once by the loss of power to extend the knee, the retraction of the patella and the localized signs of a wound or of subcutaneous trauma. The usual story of these patients, as we have seen them a year or more after their original injury, is that following a period of immobilization in full extension, with or without suture of the ligament, they were soon restored to what appeared to be a normal condition. Before long, however, sometimes after a fall in which the ligament was stretched, but sometimes without any definite history of further injury, they observed that they could not extend the knee quite to the straight line. Gradually the extensor power diminished until it disappeared completely Sometimes, on the other hand, the loss of power occurred suddenly as the result of some unusual strain placed on the ligament. In the former cases the lesion is of the nature of a slow stretching of the scar, and in the latter it is a simple recurrence of the rupture through the line of healing.

Reconstruction of a ruptured patellar ligament is made comparatively simple by the proximity of the patella and the tuberosity of the tibia to one another. The operation we perform is as follows: Through a straight or S-shaped incision on the front of the limb, the patella, the ligamentum patellae and the tuberosity and upper portion of the shaft of the tibia are exposed. The remains of the ligamentum patellae are isolated and the scar tissue removed. The ligament is then split longitudinally in the middle line from the patella to the tuberosity. Two vertical holes are now drilled through the patella with a $\frac{3}{16}$ inch drill. These holes may be crossed or parallel as shown in the diagram (Fig. 1). A hole is also drilled into the tibia at the insertion of the patellar ligament with a $\frac{5}{16}$ inch drill, and two other holes, three-sixteenths of an inch wide and an inch or more long, are drilled through the cortex of the tibia below the tuberosity and inclined so as to communicate with the larger hole in the depths of the bone. The full length of the tendo Achillis is now exposed and a segment composed of half its thickness and seven inches long is removed. The plantaris tendon is also excised for use as a suture. The segment of tendo Achillis is split longitudinally into two equal parts and these are drawn through the holes in the patella and the tibia as shown in the illustration (Fig. 1). The patella is now dragged downward as far as it will come with a sharp-hooked retractor and the new patellar ligaments drawn taut and sewn firmly into place. This is a very important stage of the operation as the complete restoration of extensor power in the knee depends on the permanent prevention of elongation of the patellar tendon. In order that the patella may be held down, therefore, until firm healing has taken place between the transplanted tendo Achillis and the holes in the bone, we take

the precaution to anchor the ends of the transplants securely to unyielding tissue or to sew them together above the patella and across the anterior border of the tibia with fine silk or linen. These materials are preferable to catgut as this may be absorbed before firm healing has taken place and so allow retraction of the patella. The final stage of the operation consists of sewing the ends of the ruptured ligamentum patellae together with a suture made from the plantaris tendon, and the closing of the vertical split in the old tendon so as to bury the new tendon completely in the remains of the old. The limb is immobilized in plaster for two months.

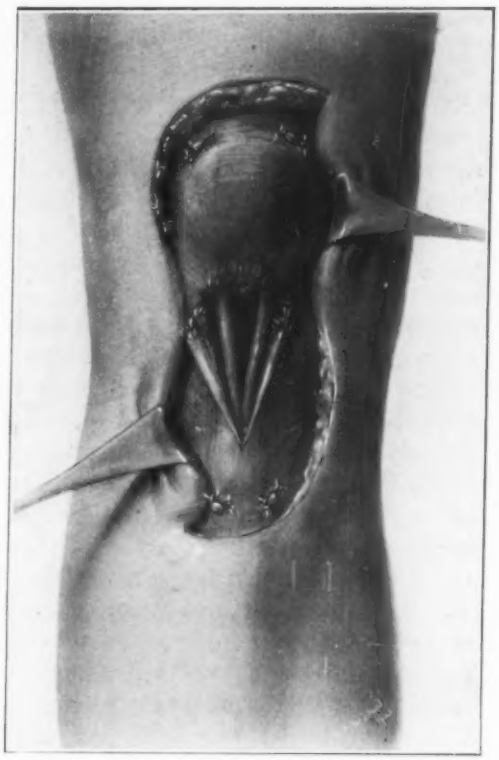


FIG. 1

Reconstruction of ruptured ligamentum patellae. Two stout strips of tendo Achillis are passed through drill-holes in the patella above and the tibia below. Their ends are sutured by silk to hold them in place until they have become firmly healed to the tunnels in the bone.

In the majority of instances of rupture of the ligamentum patellae we think it wiser to reconstruct the ligament completely as described than to trust to simple suture of the ends of the tendon with fascia. No matter how carefully the living sutures were woven into the ends of the injured tendon there would always be the possibility that they would tear out under severe strain owing to the longitudinal arrangement of the bundles of fibres. Where the injury, however, is in the form of an avulsion from the tibia, and the tip of the tuberosity has been carried away with the tendon, the complete reconstruction appears to be unnecessary. In such cases we have brought the freshened surfaces of bone together and anchored the ligament in place by means of sutures of fascia lata passed through holes in the tibia and woven securely into the ligament above the fragment of the tuberosity.

We have now the records of five patients operated upon by these methods. Each has been restored to normal. The first patient was operated upon six years ago and he has carried on as a bricklayer ever since. It would appear, therefore, that the immediate results may be expected to stand the test of time.

FRACTURE OF THE PATELLA

It is not very often that such a method as that described for rupture of the ligamentum patellae is required for fracture of the patella. It is usually possible at any time after the fracture has occurred to bring the surfaces of the fragments together and secure strong bony union. Occasionally, however, in old cases of ununited fracture, the fragments are so widely separated that all efforts to bring them together fail. Such cases can be immensely improved by joining the separated fragments together by a transplant of fascia or tendon. Phemister has reported such a case and described an operation which resulted very satisfactorily, in which the gap was bridged by a sheet of fascia lata. The cases which most frequently require such treatment are late cases in which the fracture has taken place close to the attachment of the ligamentum patellae or the quadriceps tendon so that the patella consists of one large fragment and a small one which has pulled away with the tendon. The prospect of getting union by bone in a case like this, where one fragment is a mere flake, is so remote that in such cases we advise the insertion of a heavy fascial or tendinous transplant to act as a permanent bridge across the rupture.

We have had several examples of this type of injury and have had an opportunity to apply the method to each of the varieties mentioned. The first patient was a very tall young man, weighing approximately 250 pounds, who a year previously had sustained a fracture of the patella close to the lower border, leaving a small piece of bone about the size of a marble attached to the patellar ligament. The injury had been repaired by suture with catgut but subsequently the fragments became separated and a severe disability resulted. The second was a stout elderly lady in whom the fracture occurred close to the upper border of the patella. At the time of our operation the quadriceps had drawn the flake of bone an inch and a half away from the main fragment. The third was a young man who had sustained a comminuted fracture through the middle of the patella and, in spite of suture with catgut, wide separation had resulted. The lower half consisted of an irregular mass of bone which acted as a mechanical irritant whenever the joint was moved.

The operations performed for these patients varied somewhat according to the local condition met with, but the principle was the same in all. It consisted in bringing the freshened surfaces of the fragments together, if this was possible, and fastening them there by heavy sutures of fascia or tendon (Fig. 2) or, if this was impossible, drawing them as closely together as they could be made to come and bridging the gap with fascial or tendinous sutures of sufficient strength to withstand the strain to which the quadriceps apparatus is normally subjected (Fig. 3). If bony union occurred, well and good, but if it did not the continuity of the quadriceps was restored by the transplant of fibrous tissue, which, unlike a scar, will not stretch. In the case of the third variety, where the lower portion of the patella consisted of an irregular mass of bone which would probably

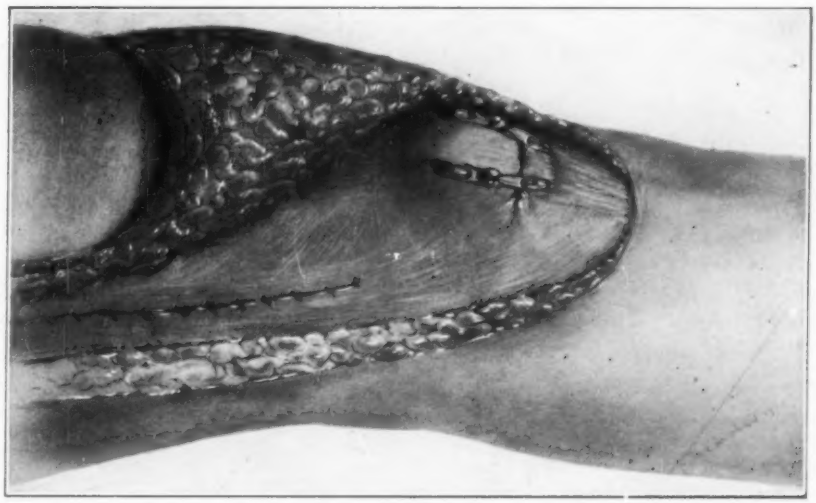


FIG. 2

Repair of an ununited fracture of the patella near its lower margin. In this case the fragments can be approximated and are held together by sutures of fascia lata passing around the lower fragment and through drill-holes in the upper fragment.

interfere with the smooth working of the joint and where close approximation of the fragments was impossible, this mass of bone was removed with a saw, leaving only a flake of bone attached to the upper end of the patellar ligament to provide security for the sutures. Up to the present we have used sutures of fascia whenever the fragments of bone could be brought together (Fig. 2) but when a gap remained to be bridged we have used a stout segment of tendo Achillis (Fig. 3). The fascial strips (Fig. 2), about half an inch in width, are inserted as ordinary sutures passed through vertical drill holes in the large fragment of the patella and woven through the tendon beyond the small fragment by means of a large-eyed needle into which the suture is tied. When the segment of tendo Achillis is used (Fig. 3) it is passed transversely through the quadriceps tendon or the ligamentum patellae, as the case may be, just beyond the small bone fragment, and the ends are then drawn through drill holes in the large fragment and sewn tightly together after the fragments have been drawn as close to one another as they can be made to come. In fastening the ends of the strips of fascia or tendon together we pass them through one another and oversew with fine linen to prevent slipping during the period before firm healing has taken place.

Repair of ununited fracture of the patella by the methods described has proved highly satisfactory. Even in those cases in which bony union of the fragments could not be secured there has been no yielding at the

point of repair and the patients are able to flex and extend the knee to the full range and have no disability whatever.

### RUPTURE OF THE QUADRICEPS TENDON

This is an injury which is comparatively common. We have seen half a dozen cases in the past two years. As a rule it occurs in the form of an avulsion of the tendon from its insertion into the patella and is followed by great distension of the joint and the area of the injury with blood and synovial fluid. In any but cases of partial rupture, open operation is a necessity as the retraction of the muscle leaves an open space above the patella which communicates directly with the joint and which ultimately becomes lined with synovial membrane. In many instances suture of the tendon to the fibrous tissue on the surface of the patella proves quite successful but, on the other hand, it frequently fails owing to stretching of the scar. We are of the opinion, therefore, that even in the recent cases some form of suture with living material is advisable. In the late cases, however, there is no such choice in the form of suture, as failure is almost certain if we place our dependence on catgut or silk.

FIG. 3

Repair of ununited fracture of the patella near its lower margin. In this case an irregular mass of bone, the result of comminution, was removed from the lower fragment, and accurate apposition was not possible. The repair was therefore obtained by a long strip of tendo Achillis, passing around the lower fragment and through drill-holes in the upper fragment. The operation was completed by getting as intimate a contact as possible between the two ends of the tendinous transplant, passing one through the other and suturing them together by silk with considerable overlap.

The operation we have performed is as follows (Fig. 4): Through a vertical median incision the synovial protrusion above the patella is opened. The walls of this protrusion are excised, leaving only sufficient synovial membrane to permit the closure of the suprapatellar pouch of the knee joint. Several vertical holes are then drilled through the patella for the reception of the sutures. Long strips of fascia lata are obtained from the lateral aspect of the thigh and tied into large-eyed needles. These sutures are passed through the holes in the bone; both ends are then woven several times through the tendon, tied, and the knot transfixed with silk. No definite method of inserting the sutures is recom-

mended as each case presents its own problem. The principle should be observed, however, that the strips of fascia shall be securely woven into the tendon and that they shall have a solid anchorage in the bone. Sufficient fascia should be used to make the bond of union approximately equal in strength to the normal quadriceps tendon. We think it unwise to cut off too freely the scar tissue which covers the end of the ruptured tendon, as it is useful in preventing the fascial sutures from cutting out when strain is applied. We content ourselves, therefore, with merely freshening the surface of the patella and the end of the ruptured tendon before drawing them into apposition.

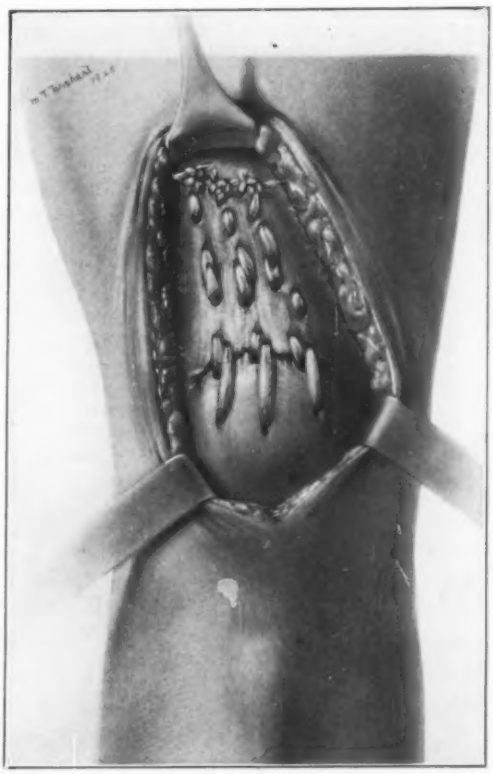


FIG. 4

Repair of ruptured quadriceps tendon. In this case three long sutures of fascia lata have been used, each passing through a tunnel in the bone, with either end woven several times through the tendon. The security of the fixation to the tendon is increased by interweaving the stitches and by tying the ends in a triple knot, reenforced by a silk suture.

A few general points in the technique of these operations are worthy of observation. In order that transplants of tendon or fascia may heal firmly to bone, they should be thoroughly freed of their areolar coverings and scarified. They should fit fairly snugly the tunnels through which they pass. Care should be taken in the case of sutures of fascia lata that the ends are securely fastened with fine linen or silk, as simple knots in this tissue are exceedingly likely to loosen. Reference to the technique of preparing and handling sutures of fascia or tendon may be found in a previous paper (Canadian Medical Association Journal, July, 1921).

Of the permanence of these transplants of tendon and fascia there can be little doubt. We have examined them in animals two years after their insertion and as far as we could see, both in the gross and microscopically, they were unchanged. Clinically they can be demonstrated by palpation through the skin as late as seven years after their insertion.

While this paper is devoted primarily to the late repair of injuries of the quadriceps apparatus, much that has been said applies equally well to their early treatment. Rupture of the quadriceps tendon and ligamentum

patellae and avulsion of these structures from their bony attachments undoubtedly call for open operation to make possible the proper reposition of the torn and separated tissues. The uncertainty of the repair, however, even after open operation, suggests at once the wisdom of applying to fresh injuries of this type the principle of treatment which has proven so helpful in the late cases. It has become our custom, therefore, in operating, to repair these injuries, to substitute for the ordinary absorbable or non-absorbable materials sutures made from fascia lata or tendon. While the operation is lengthened by the additional dissection which is necessary and the technique is undoubtedly made more tedious, the additional trouble is made well worth while by the certainty that the operation will not result in failure through the stretching of a scar. We have little doubt that if the principle is adopted in the early treatment the necessity for late operation will gradually disappear.

# OSTEOCHONDRITIS OF THE VERTEBRAL BODY*

BY JOSEPH BUCHMAN, B.S., M.D., BROOKLYN, N. Y.

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In a recent issue of *The Journal of Bone and Joint Surgery*, Calvé[1] described a new disease entity under the caption of "A Localized Affection of the Spine Suggesting Osteochondritis of the Vertebral Body with the Clinical Aspects of Pott's Disease". He cites two cases, one of his own and one of Brackett's. In May, 1925, at the meeting of the American Orthopaedic Association, Dr. Gallie in discussing my paper[2] on "Vertebral Epiphysitis" referred to a case of his which evidently falls into the same group. These are apparently the only three cases on record. A brief review of these cases shows that they were two and a half, five, and seven years of age. None gave a history of serious injury. They were characterized by an insidious onset, fatigue, pain, stiffness of back and knuckle formation. One had night cries. X-ray examination revealed a shortening of the vertical diameter of one of the vertebrae. All of these cases responded to a comparatively short period of treatment by recumbency and support. It was only after the rapid cure that the observers became suspicious and recognized these cases as being distinct from Pott's disease for which they were mistaken.

Since the above mentioned publication, I have had the good fortune to observe two similar cases on the Service of Dr. Royal Whitman at the New York Hospital for the Ruptured and Crippled. In presenting my observations, I hope to aid in crystallizing this entity and to differentiate it from vertebral epiphysitis.

CASE 1. Margurite M., five years of age, was brought to the Out Patient Department after having fallen a distance of fifteen steps, six days previously and having sustained an injury to her back. Thereafter, the mother noticed a kyphos in the upper dorsal region and a prominence of a part of the chest, anteriorly. The child complained of pain in the back and of "leaning over in a heap after playing for a while". She was restless at night and could not lie down without pain in the back. These symptoms had been present for an indefinite period before the injury. Four months previously, the child had had measles and scarlet fever. There was no history of rickets nor were there any indications of syphilis or tuberculosis in the family.

Physical examination showed a fairly well nourished and fairly well developed child of five years of age, in good general health. Her posture was poor. The back was symmetrical, and the spine was in the median line. In the upper portion of the dorsal region there was an exaggerated rigid posterior curvature while the lumbar seg-

*From the Service of Dr. Royal Whitman, Hospital for the Ruptured and Crippled, New York.

FIG. 1. CASE 1
Showing posterior curvature.

FIG. 2. CASE 1
Showing round shoulders.

ment of the spine presented a compensatory lordosis. There was no knuckle formation and no muscle spasm. There was questionable tenderness over the spinous processes of the dorsal region. Anteriorly the left side of the chest was somewhat more prominent than the right. There was a questionable Harrison's groove. There was no rosary, coxa vara, knock knees, bow legs or enlarged epiphyses (Figs. 1 and 2).

X-ray examination showed in the anteroposterior view that the vertical diameters of the upper dorsal vertebrae were diminished in varying degrees; the diminution in size was greatest in the sixth and least in the fifth dorsal vertebra. The intervertebral discs were increased in height in proportion to the diminution of the height of the bodies. The eighth, ninth and tenth dorsal segments presented indistinct upper and lower outlines and the adjoining intervertebral spaces were diminished and hazy in appearance (Fig. 3). The lateral view showed a definite kyphosis involving the upper dorsal region. The upper eight dorsal vertebrae were diminished in their vertical diameters in varying degrees, reaching a maximum of diminution in the sixth segment. These bodies were all wedge-shaped and their upper and lower outlines were regular but definitely denser than in other portions of the spine. The intervertebral spaces were wider in proportion to the flattening of the bodies (Fig. 4).

The history of injury in this case is, in my opinion, inconsequential. It has only served to call the mother's attention to a condition which has been present for some time. It is unlikely that after an injury of such proportion as to produce the marked changes noted the child would be as comfortable and as symptomless as the examination revealed.

CASE 2. Evelyn V., 11 years of age, came to the Out Patient Department complaining of pain in the back, of three weeks' duration. At the age of twenty months,

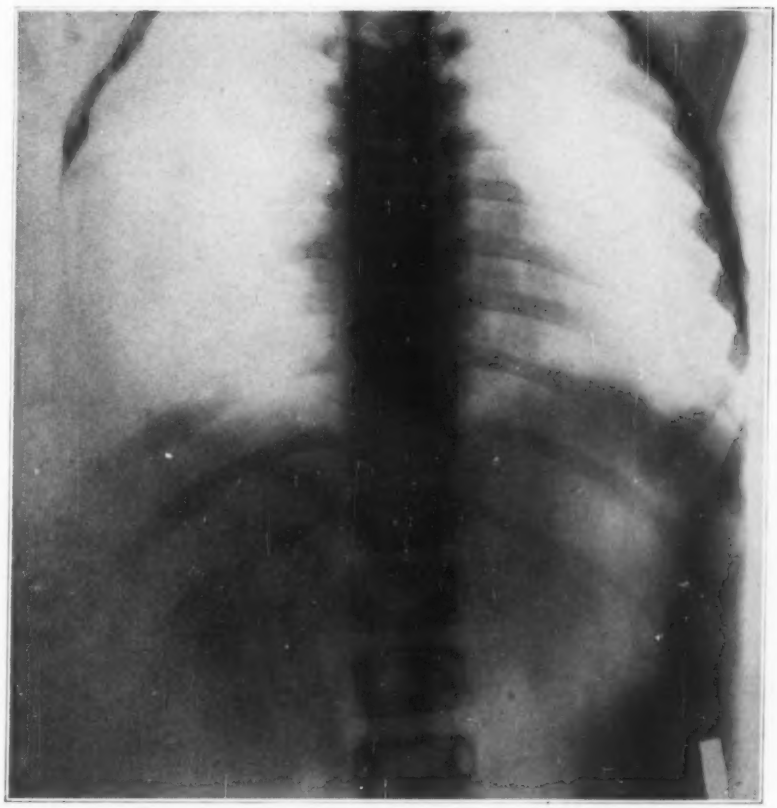


FIG. 3. CASE 1

Showing diminution of vertical diameters of the upper dorsal vertebrae, proportional increase in height of intervertebral discs, and indistinct superior and inferior outlines of the eighth, ninth and tenth dorsal vertebrae with diminution and hazy appearance of the intervertebral spaces.

the mother had noticed a deformity of the back. At that time the condition was thought to be congenital scoliosis and was treated for five years with plaster-of-Paris jackets. The treatment was then discontinued and the deformity remained at a standstill until three weeks ago when pain reappeared in the interscapular region. The child has had very many sore throats and a nasal obstruction. Her father died of tuberculosis.

Examination showed a well developed, somewhat overnourished girl in good general health. Her posture was poor and there was a moderate degree of round shoulders. The back was asymmetrical and the spine was deviated to the right in the lower dorsal and to the left in the dorso-lumbar region. There was a moderate degree of muscle spasm and tenderness over the spinous and transverse processes of the dorsal and lumbar segments of the spine. Both iliac crests were tender. All motions of the spine were moderately limited.

X-ray examination showed a low right dorsal, left dorso-lumbar scoliosis. The twelfth dorsal and first lumbar vertebrae were wedge-shaped. The outlines of these two vertebrae were indistinct and irregular and tended to produce a fused mass appearance at their right margin. The intervening intervertebral space was very irregular and hazy. The intervertebral discs of the entire dorsal spine were diminished in height and irregular and the vertebral outlines of the same area were indistinct and irregular to a less extent.

FIG. 4. CASE 1

Showing diminution in height of the upper dorsal vertebrae, wedging of these segments and increase in height of the intervertebral discs. The superior and inferior outlines of the affected vertebrae appear dense.

The fifth lumbar vertebra was asymmetrical (Fig. 5). The oblique lateral view of the dorsal region showed an irregularity of the vertebral outlines, a fragmentation of the epiphyses wherever seen and an irregularity and haziness of the intervertebral spaces (Fig. 6). The lateral view of the dorso-lumbar region showed that the twelfth dorsal was only one half as high as the vertebrae above and below, and was somewhat wedge-shaped. The first lumbar was about three-fourths of its normal height and was wedge-shaped. These two vertebrae with those above them tended to produce a fused mass appearance (Fig. 7).

It was my good fortune to find among the private records of Dr. S. Kleinberg a photograph of the anteroposterior roentgenogram taken on January 19, 1914, when the child was first seen. This picture showed a flattening, widening and wedging of the twelfth dorsal and first lumbar vertebrae. Their outlines were irregular and the intervertebral disc between the eleventh and twelfth dorsal segments was widened (Fig. 8).

It became evident at once that this patient originally suffered during her first period of rapid growth from an osteochondritis of the vertebral body proper. At the end of this period the condition subsided only to flare up again as an affection of the epiphyses during the second period of rapid growth when the growth takes place at the superior and inferior vertebral epiphyses—i.e., vertebral epiphysitis.

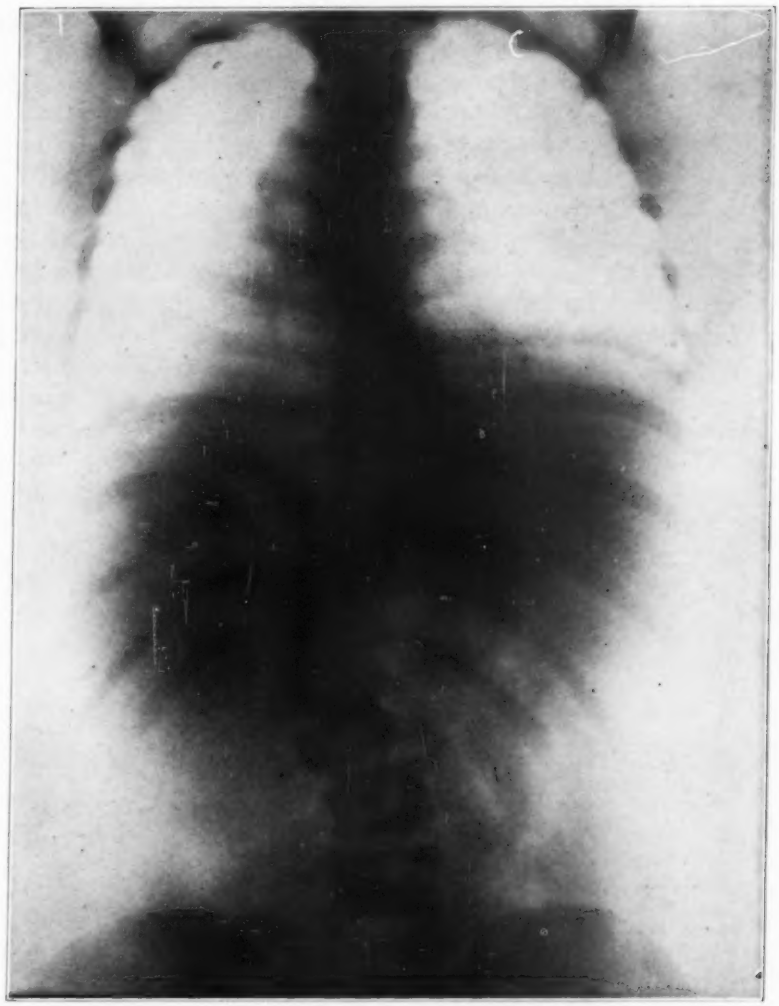


FIG. 5. CASE 2

Showing wedging of the twelfth dorsal and first lumbar vertebrae, fused mass appearance to right, indistinctness and irregularity of vertebral outlines.

A brief review of the ossification processes of the vertebrae will clarify the basis for differentiating these two kindred conditions. Poirier[3] teaches that all ossification centers of the vertebrae are divided into primary and secondary centers. The primary centers begin to appear on the forty-fifth day and are all present by the fourth month of intra-uterine life. These centers consist of fundamental and complementary ossific points. The former are the central and the neural, the latter are the central posterior and the transverse. These fundamental and complementary ossific points fuse very early in life. The secondary centers of ossification appear between the eighteenth and twentieth year of life. These are divided into

those that are common to all the vertebrae and those that are found only in some of the vertebrae. The former are the superior and inferior body epiphyses, the transverse, the spinous process and the superior articulating epiphyses; the latter are the costal epiphyses in the dorsal vertebrae and the mammillary epiphyses in the lumbar vertebrae (Figs. 9 and 10).

More recent studies of Koehler[4], Delahaye[5], Mau[6] and myself have shown that, of the secondary ossific centers, the superior and inferior body epiphyses appear much earlier—i. e., at the eleventh and twelfth year. It is therefore very evident that one cannot speak of an epiphysitis before the epiphyses have developed. On the other hand, during the second stage of rapid growth the disturbance cannot be referred to as an osteochondritis of the centrum for the greatest derangement is in the epiphyseal area of growth and it would therefore be more proper to speak of it as an epiphysitis.

The age incidence of osteochondritis of the centrum in the five cases referred to above is one and three-fourths, two and one-half, five, and twice seven years. Vertebral epiphysitis is rarely seen before eleven years of age unless there is a premature ossification of the epiphyses as one occasionally finds. These two affections are undoubtedly parallel conditions going on in different periods of growth and in different foci, possibly merging into each other but more probably separated by an interval corresponding to that between the two periods of rapid growth.

It is indeed very tempting and I trust not too presumptuous to paint

FIG. 6. CASE 2

Oblique lateral roentgenograms showing irregularity of vertebral outlines, a fragmentation of the epiphyses wherever seen and a haziness of the intervertebral spaces.

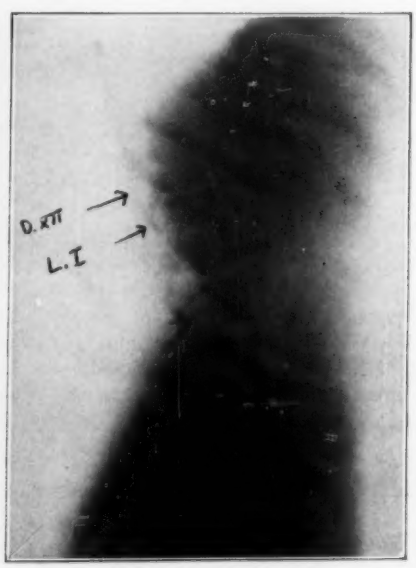



FIG. 7. CASE 2

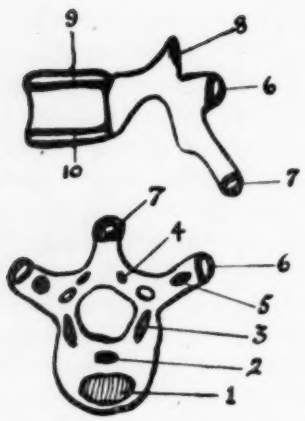
Showing the twelfth dorsal vertebra half its normal height, the first lumbar three-quarters its normal height and the fused mass appearance of these vertebrae and those above them.

a composite picture of this condition based on the five cases observed and the parallelism that seems to exist between it and vertebral epiphysitis, Calvé-Legg-Perthes' disease, Osgood-Schlätter's disease, Koehler's disease, coxa vara cervicalis and all the other osteochondritides that have been recently described. The age of onset is the period of most active growth for the area involved. In the case of the vertebral bodies, the onset is during the first few years of life. The symptoms are moderate or slight, for the amount of pathology indicated on the roentgenogram. The disturbing factor is deformity which is subsequential. There is moderate pain, tenderness, spasm, limitation of motion and finally fixed deformity of the back. There may or may not be a knuckle, depending upon the extent of the area involved. The deformity may be a kyphosis or a scoliosis depending upon secondary factors of stress and strain.

A study of Calvé's case reports and the roentgenographic findings in

FIG. 8. CASE 2

(By courtesy of Dr. S. Kleinberg.) Showing a flattening, widening and wedging of the twelfth dorsal and first lumbar vertebrae with irregular outlines and widening of the intervertebral disc between the eleventh and twelfth dorsal vertebrae.




FIGS. 9 and 10

Schematic representation of ossific centers of vertebrae (after Poirier). (Drawn by Dr. Nicola.)
Primary Ossific Centers: (1) Central, (2) Central Posterior, (3) Neural Anterior, (4) Neural Posterior, (5) Transverse.
Secondary Ossific Centers: (6) Transverse Process, (7) Spinous Process, (8) Superior Articulation, (9) Superior Body, (10) Inferior Body.

my two cases shows that in some the x-ray shows a roughened irregular outline of the vertebrae involved while in others the outlines seem to be condensed. This is parallel to the other known forms of osteochondritis. First, there is an irregular, moth-eaten, mottled, porous appearance of the affected area, to be followed by the stage of regression when the calcification processes set in to form the dense sclerosed appearing outlines. In Calvé's cases only one vertebra was involved. Of my cases one showed an involvement of the upper eight dorsal vertebrae in varying degrees while the second case showed an involvement of the twelfth dorsal and first lumbar vertebrae. Four of the cases presented kyphoses, while only one developed a scoliosis.

A discussion of the etiology of the osteochondritis of the vertebral body must perforce be theoretical, and in the main by analogy with the other forms of osteochondritis that have been more thoroughly observed and studied. Calvé in considering this phase of the subject eliminates tuberculosis, syphilis, Kümmel's disease and congenital malformation. He believes that an infectious origin is the more probable of all the etiological factors.

Histological studies of Perthes' and Koehler's disease by Axhausen[7, 8] and others have revealed areas of necroses but no persistent evidence of inflammatory processes or infective organisms. It is the theory of the above investigators that these disturbances are caused by bland, non-septic emboli which lodge in the epiphyseal areas. The objection was raised that the disease is found only in areas subject to great mechanical stress and strain. He therefore added the compression fracture conception indicating that the emboli may be present in many of the epiphyses of the body but that only in those areas subject to stress and strain are we able to find it clinically, for in those areas that are free of these influences, the healing processes set in and the parts are reconstituted.

In a lengthy dissertation on the etiology of vertebral epiphysitis Mau[6] expresses the belief that the embolic theory in association with the compression fracture addendum of Axhausen is highly improbable. He thinks that the compression fracture due to mechanical stress and strain is the

only part of the theory that is acceptable. His objections are based on the multiplicity of the foci on both sides of the epiphyseal plates and over several adjoining vertebrae at a period of greatest growth. It is a far fetched coincidence that so many emboli should lodge in a fairly constant area, during a constant period of life. His greatest objection is based on his histological studies of these epiphyses. Microscopically, no blood vessels are demonstrable in the epiphyseal areas of the vertebrae. It is only in his twenty-year-old specimens that blood vessels can be demonstrated. At sixteen years of age there is no real ossification present. All that can be found are areas of calcification. Only at twenty years of age does ossification as such occur. He therefore argues that, there being no blood vessels, there consequently cannot be embolism.

Mau then attempts to explain the necroses on the basis of congenital hypoplasia of the blood supply to the growing areas which is sufficient during the periods of slow growth but which becomes inadequate during periods of rapid growth. Also, that stress and strain might cause an angiospasm in these areas. He admits, however, that these considerations do not have any more proof in support than can be brought to bear in support of Axhausen's theory.

More recently Murk Jansen[9] propounds the theory in connection with his discussion on "March Foot" that bones may become brittle through stasis of blood and lymph, thus enhancing the possibility of the characteristic compression fracture described by Axhausen. Jansen describes a very plausible mechanism causing the stasis in the case of the metatarsal bones but fails to suggest the mechanism in the osteochondritides. Furthermore, the objection applicable to the other blood vessel theories are just as applicable in this pathogenic concept.

Scheuermann[10], Delahaye[11, 12], Hahn[13] and others[14, 15] who have written on vertebral epiphysitis agree that the disturbance lies in the epiphyseal areas. My own observations are in accordance with those of the above writers. The roentgenologic change seen is the same as that found in coxa vara, genu valgum and genu varum of adolescence. Mikulicz's[16] studies of the latter growth disturbances show that they are similar in appearance to late rickets. The works of Looser[17], Fromme[18], Schmorl[19] and Recklinghausen[20] have established that there is such an entity as late rickets. Furthermore, the pathological appearances are similar to those found in osteomalacia. The latter two conditions can only be differentiated clinically. Finally, we have three conditions: the weight-bearing deformities of adolescence, such as coxa vara, genu valgum and genu varum; late rickets, and osteomalacia each presenting the same pathological appearances but different clinical aspects. The only conclusion that can be drawn from this series of facts is that of Schanz[21], namely,—that the pathologic picture is not specific but is a response to the increased static demand over the static capacity. This disturbed relationship between the static demand and static capacity (Statische Inanspruchname uber die Statische Leistungsfähigkeit) may be precipitated by an increase in static

demand, a decrease in static capacity, and a combination of both factors.

This is in accordance with Whitman's[22] contentions in connection with coxa vara cervicalis when associated with Froehlich's syndrome, namely,—that the etiological factor is not the endocrine dyscrasia, but the increased load that is thrown upon a weakened epiphysis. Therein lies, I believe, the explanation for the frequent occurrence of slipped femoral head epiphyses in individuals with Froehlich's syndromes and the occurrence of vertebral epiphysitis and slipped femoral epiphyses in several of my cases which are frankly endocrine in nature.

Whitman further states: "Coxa vara may be classed as one of the group of static deformities caused by a disproportion between the strength of the supporting structures and the burden that is put upon it. The support may be disproportionately weak, because of inherited or acquired delicacy of structure or lack of resistance; it may be weakened by injury or by disease, or it may be overburdened by weight or strain."

Mau enumerates the various factors that upset this balance of stress and strain versus capacity. The most frequent cause of disturbance is the diminution of the capacity of the parts to bear stress and strain. Physiological studies have shown that during the periods of growth the strength of bone is diminished. Tripier[23] has shown that the epiphyses of the extremities are widest between three and five and fourteen and seventeen years of age when growth is most rapid. This is further in accordance with Murk Jansen's law of vulnerability of rapidly growing cells which is to the effect that the rapidly growing cells become hypo-active or insufficient sooner than slowly growing cells. Pathological conditions that may cause a diminution of the capacity to bear stress and strain are the disturbances of the calcium and phosphorous metabolism such as occur in infantile rickets, late rickets, osteomalacia and the types resulting from the hunger blockade of the World War. Another group of conditions are those resulting from atrophy or disuse as after prolonged immobilization in plaster-of-Paris or the reflex atrophy of Sudeck subsequent to trauma or inflammatory processes. A third group of conditions are those resulting from a weakening of the soft parts as in the asthenic type of individuals, long weakening illnesses, prolonged stay in bed, undernourishment and poliomyelitis.

The factors that increase the static demand are those due to habitual carrying of loads and habitual assumption of faulty attitudes. Mau cites a number of experimental studies showing that these factors cause a disturbance in the regularity of the growth of the epiphyses. I might add at this point that excessive obesity as in Froehlich's syndrome is a factor in increasing the static demand.

Furthermore, any combination of the above mentioned factors, those involving an increase in demand upon the structures and those causing a diminution of the capacity of the structures, may combine to disturb the balance.

Clinically my observations have been that the physiological weakness incidental to rapid growth is the most common causative factor in producing the type of osteochondritis under consideration. Delahaye stresses the same point in speaking of vertebral epiphysitis. Hard labor seems to be the more usual causative agent in the experience of Scheuermann, Mau and Valtancoli[15]. I have seen several cases that may be due to undernourishment and the German writers have cited instances apparently due to the hunger blockade. Atrophy secondary to trauma, and infection are fairly common causes in my experiences. There are, however, no observations by other writers or by myself of epiphyseal derangement in frank cases of poliomyelitis and infantile rickets. In these conditions the epiphyses appear normal even though there is gross spinal deformity.

## CONCLUSIONS

1. Vertebral osteochondritis is an entity distinct from vertebral epiphysitis though fundamentally they are similar processes with similar characteristics occurring at different growth periods.

2. Vertebral osteochondritis sets in during the first few years of life and is characterized by moderate or very slight pain, fatigue, night cries, muscle spasm, tenderness, deformity in the form of a knuckle or a generalized kyphosis or scoliosis.

3. Roentgenographically it is characterized by an irregularity of the vertebral outlines, flattening, and wedging of the vertebrae to be followed by the stage of restitution when the vertebral outlines appear dense and sclerosed. Deformity of the vertebral bodies is the final result. The intervertebral spaces are widened in proportion to the thinning of the vertebral bodies.

4. Of the five cases referred to in this communication, three were mistaken for Pott's disease and treated as such, one was mistaken for congenital scoliosis and only one was diagnosed as vertebral osteochronditis.

5. The etiology is unknown. From theoretical and analogous clinical observations and pathological studies it seems that an imbalance between the static demand and static capacity is a likely cause of this disturbance.

6. This static imbalance is most likely to occur during the first and second periods of rapid growth—in spine cases from birth to six years of age and about eleven to sixteen years of age.

7. All of the treated cases have done well under recumbency and plaster-of-Paris jacket treatment.

8. All of the treated cases have a remaining deformity which does not interfere with activity.

## REFERENCES

1. Calvé, Jaques: A Localized Affection of the Spine Suggesting Osteochondritis of the Vertebral Body with the Clinical Aspects of Pott's Disease. J. Bone and Joint Surg. VII, 41, Jan. 1925.
2. Buchman, Joseph: Vertebral Epiphysitis—A Cause of Spinal Deformity. J. Bone and Joint Surg. VII, 814, Oct. 1925.

3. Poirier, P., Charpy, A., et Cunéo, B.: Abrégé D'Anatomie, Paris, Masson et Cie., I, 119, 1908.
4. Koehler: Quoted by Scheuermann.
5. Delahaye, André: Quelque Détails de L'Ossification Vertébrale Précisés Par La Radiographie. J. de radiol. et d'electrol. VIII, 167, April 1924.
6. Mau, C.: Die Kyphosis dorsalis adolescentium im Rahmen der Epiphysen und Epiphysenlinienerkrankungen des Wachstumsalters. Ztschr. f. orthop. Chir., XLVI, 145, 1924–25.
7. Axhausen, G.: Der Krankheitsvorgang bei der Köhler'schen Krankheit der Metatarsalköpfchen und bei der Perthesischen Krankheit des Hüftkopfes. Zentralbl. f. Chir., L, 553, 1923.
8. Axhausen, G.: Die Köhlersche Erkrankung der Metatarsophalangealgelenke. Med. Klin., XIX, 561, April 29, 1923.
9. Jansen, Murk: March Foot. J. Bone and Joint Surg., VIII, 262, April 1926.
10. Scheuermann, H.: Kyphosis dorsalis juvenilis. Ztschr. f. orthop. Chir., XLI, 305, 1921.
11. Delahaye, André: Étude sur quelque Diagnostics de Mal de Pott en particulier de l'Épiphysite vertébrale de croissance. Travail de l'Hôpital Maritime de Berck, Paris, 1924.
12. Sorrell, Etienne, et Delahaye, André: Des Épiphysites de croissance et en particulier de l'Épiphysite vertébrale douloureuse des Adolescents. Presse méd., XXXII, 737, Sept. 10, 1924.
13. Hahn, Otto: Kyphosis Osteochondropathica. Klin. Wchnschr. I, 1098, May 27, 1922.
14. Mathieu, Paul; Massart; et Ducroquet, R.: La Cyphose douloureuse et l'Épiphysite vertébrale de croissance. Bull. et mém. Soc. de chir. de Paris. LI, 220, Feb. 18, 1925.
15. Valtancoli, G.: L'Osteocondrite Deformante Giovanile Vertebrale. Riforma med. XLI, 823, Aug. 31, 1925.
16. Mikulicz: Quoted by Mau.
17. Looser: Quoted by Mau.
18. Fromme: Quoted by Mau.
19. Schmorl: Quoted by Mau.
20. Recklinghausen: Quoted by Mau.
21. Schanz: Quoted by Mau.
22. Whitman, Royal: A Treatise on Orthopaedic Surgery, Ed. 6, Philadelphia, Lea & Febiger, 1919.
23. Tripier: Quoted by Mau.

# REGENERATION OF THE SYNOVIAL MEMBRANE FOLLOWING TYPICAL SYNOVECTOMY

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Just what happens following typical synovectomy is a subject of common interest and conjecture. It has been said that, although theoretically we hope for synovial membrane replacement, practically we know that this does not take place. However, the clinical reports by Swett[1], Jones[2], Speed[3], and Steindler[4] do not bear out this contention. Quite to the contrary, it would seem that their experiences indicate that we may reasonably expect a satisfactory degree of permanent function to follow typical synovectomy, in properly selected cases. This being true, it seems only reasonable to assume that not only does synovial membrane regeneration take place, but that the pouch produced must resemble very closely the normal in structure, size and contour if restored function is to be permanent.

Previous to the report of Key[5], one year ago, it was apparently the general belief that regeneration of synovial membrane took place largely as the result of extension over the denuded surface from remaining synovial pouch tags, rather than by specialization of new fibrous tissue cells. Speed, in his article read before this Association two years ago, reminded us that the entire knee joint is at first an undifferentiated mass of mesenchymal cells which become condensed in the region of the joint. About the eighth week, by a process of liquefaction or separation in the center of this mass, a transverse cleft appears which forms the cavity of the joint. Later, as a result of selective differentiation, the cells adjoining this cavity are transformed into articular cartilage, into connective tissue which forms the joint capsule, and the remainder into the lining cells of the synovial membrane. Hence, it is not difficult to conceive of connective tissue cells reverting to their original habit and producing a new synovial membrane when occasion demands it. In support of this theory may be mentioned the excellent work of Key, who concludes his article by stating: "The new synovial membrane is formed *in situ* by metaplasia of underlying connective tissue cells and there is little or no tendency for surface growth from the edges to cover the denuded area as occurs in the repair of a defect in an epithelial surface"[5].

In typical synovectomy an effort is made to remove completely that portion of the synovial membrane which constitutes what we choose to call the anterior joint pouch. In most instances it is also deemed advisable to sacrifice the infrapatellar fat pad. It occurred to us that an analogous condition could be produced experimentally by doing a typical synovectomy upon the knee joints of dogs. In November, 1924, we began this experimental work and since that time twenty-four joints have been operated on according to the technique to be described. The recovered joints have

been studied, not only as to synovial membrane regeneration, but also in reference to new joint pouch formation.

## TECHNIQUE

Dogs, varying in age from two or three months to several years, were used. Under ether anaesthesia, the knee and adjacent area were scrubbed with green soap and water and then shaved. The skin was dried with ether and painted with 5 per cent. tincture of iodine. Ten minutes later a second coat of iodine was applied, just before the field was draped for operation. A slightly curved skin incision was made, extending from a point well above the upper limit of the anterior pouch of the knee joint, a little to the inner side of the patella, to the tibial tubercle. The skin was freed from the deep layer of the superficial fascia and retracted well out of the operative field after the application of small towels and towel clamps. The deep layer of the superficial fascia was divided on a line with the center of the patella. After retracting this tissue well out of the way, the joint capsule was opened by a median incision both above and below the patella. The patella was divided with rongeur forceps to prevent injury to the underlying structures. Four stay sutures were placed through the capsule at the upper and lower poles of the split patella, two on either side, and clamps attached to these sutures served as retractors during a major portion of the operation. The synovial membrane of the anterior surface of the femur was cut away from the femur below, and the patellar margin above. By increasing the traction upon the edges of the wound, at the same time flexing the knee, the condyles of the femur were exposed and that portion of the joint pouch lateral to the condyles, and extending forward to the patella on either side, was carefully removed, making certain that no synovial tags were left. The infrapatellar fat pad was removed *en masse*, along with the alar ligaments in most instances. The semilunar cartilages, the lateral ligaments, and the posterior joint space were not disturbed. The capsule was closed with interrupted sutures of number 0 chromic catgut. The deep layer of the superficial fascia was next sutured with continuous number 0 plain catgut, hoping to oppose a barrier against superficial infection should it occur. The skin was closed with interrupted dermal sutures and covered with a collodion dressing. A simple dry dressing held by adhesive tape was applied over all. A tourniquet was not used, nor were immobilizing splints applied.

Twenty-four knee joints were operated on, with but three infections. One deep infection destroyed the joint of an old dog who removed the dressings and tore open the wound some time during the night following operation. The second deep infection could be accounted for by a recognized error in technique. The third infection was superficial, further extension apparently being prevented by the deep layer of the superficial fascia acting as a barrier. In most instances the dogs removed the superficial dressings within the first forty-eight hours, but in only the one

case mentioned did they remove the collodion dressings or interfere with the sutures.

In order that function in the operated knee might be encouraged, the opposite joint was usually operated upon within ten to fourteen days, thus forcing the dogs to use the first joint. It was noticed that the younger, more playful pups regained motion much more quickly than did the older dogs.

### POSTOPERATIVE CLINICAL OBSERVATIONS

It was our observation that in most instances the postoperative reaction was very moderate. During the first three days there was considerable local swelling, moderately increased heat, but little pain produced as the result of a reasonable range of forced motion, which the dogs tolerated without resisting. After the third day the swelling slowly subsided, and in the younger, more active pups voluntary motion and incomplete function were begun. By the tenth to the fourteenth day the swelling had largely disappeared and weight-bearing was usual, though the dogs still limped. After the fourteenth day complete function rapidly returned in all non-infected joints, excepting in dog number five, referred to later in our report.

### METHOD OF JOINT STUDY

The table below indicates the number of joints examined and the corresponding postoperative day on which the dog was sacrificed:

| *Number of Joints* | *Number of Postoperative Days* |
|---|---|
| 1 | 1 |
| 2 | 3 |
| 2 | 7 |
| 2 | 10 |
| 1 | 11 |
| 1 | 16 |
| 1 | 22 |
| 2 | 28 |
| 1 | 31 |
| 1 | 31 |
| 1 | 35 |
| 1 | 42 |
| 1 | 45 |
| 1 | 49 |
| 1 | 86 |
| 1 | 89 |
| 1 | 108 |
| Total 21 | |

Following the administration of lethal ether, the joints were excised and immediately examined. The first few joints were opened by a posterior approach, but most of them by separation along the line of the operative incision. Macroscopic observations were recorded, and the specimens

immediately placed in 10 per cent. formalin solution awaiting preparation for histological study. The character and amount of joint fluid was observed, but its microscopic study was omitted.

In order to demonstrate the development of the anterior pouch, nine joints were injected with a 12½ per cent. sodium iodide solution under low pressure, and x-rays were taken. In this way it was possible to demonstrate the early formation of a definite limiting membrane, as well as to study the relative size and contour of the newly forming pouch at various stages of its development (Figs. 1–8).

## MACROSCOPIC STUDY OF THE JOINTS

Macroscopic studies were made immediately after excision and included the recording of observations made in regard to wound-healing, degree of function, character of the joint fluid, relative size and contour of the joint pouch, character and location of blood clots and adhesions, surface appearance of denuded areas, effect of fringes overhanging cartilage surfaces, cartilage changes, frequency and location of villous formation, and a study of the contents of the infrapatellar fat pad.

*Primary wound healing* was secured in twenty-one of the twenty-four joints operated upon. Firm bony union of the patella occurred in sixteen cases, leaving only a fine linear scar on the articular surface to indicate the line of division. Strong fibrous union between the widely separated fragments of the patella resulted in five cases. By the fifth or the seventh day, the sutures entering the joint space were covered over by a smooth layer of tissue.

*Function* began to return in most cases with the recession of the post-operative soft tissue swelling. From the third to the sixth day only a few degrees of voluntary motion were noted. From the seventh to the fourteenth day the dogs hopped about, occasionally touching the foot to the ground when standing. During the next week, weight-bearing was begun, at first with a decided limp, but by the end of the fourth week full motion was restored. All dogs allowed to live beyond the fourth week had a return of normal function in the joint operated upon, with the exception of dog number five. In this instance, each knee functioned very poorly. Our records showed this to be one of our older dogs who refused to use his knees following the operation.

*Joint Fluid:* After twenty-four hours the joint fluid examined was thin and serosanguineous. By the end of the third day it was a clear, brownish fluid and its viscid property was beginning to reappear. After the sixth to the tenth day the fluid was clear, straw-colored and but slightly increased in amount. From this time on it rapidly assumed normal characteristics.

*Development of the Joint Pouch:* The macroscopic study of joint pouch development proved to be, perhaps, the most interesting phase of the work. The precision and regularity with which the various stages developed were most striking. Immediately following the operation, the knee was distended with free blood. It appeared that after twenty-four hours the

FIG. 1

Dog No. 9. Left knee joint—Normal.

FIG. 2

Dog No. 12. Left knee joint—3 day specimen.

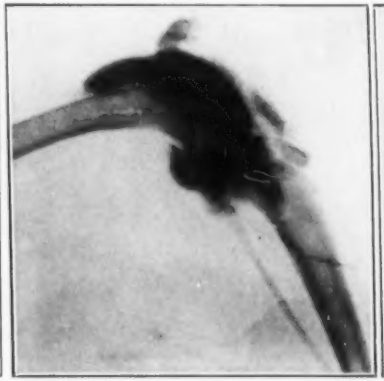

FIG. 3

Dog No. 12. Right knee joint—10 day specimen.

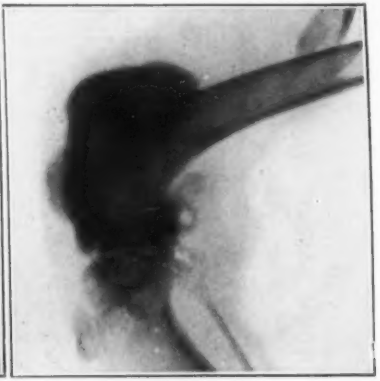

FIG. 4

Dog No. 16. Right knee joint—10 day specimen.

FIG. 5

Dog No. 10. Left knee joint—49 day specimen.

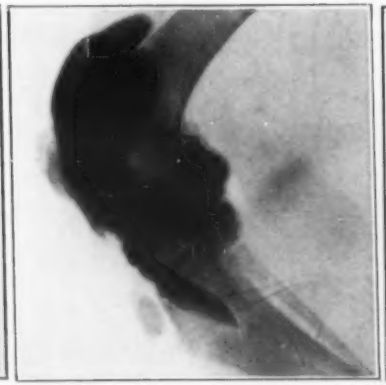

FIG. 6

Dog No. 10. Right knee joint—31 day specimen.

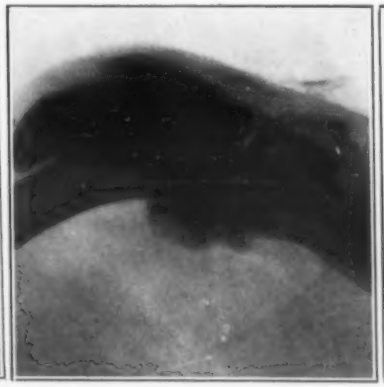

FIG. 7

Dog No. 7. Right knee joint—86 day specimen.

FIG. 8

Dog No. 9. Right knee joint—89 day specimen.

Roentgenograms of the knee joints of dogs following injection of sodium iodide solution.

FIG. 1. Normal joint. FIG. 2. Three day specimen illustrating the boundaries of the new anterior pouch. FIG. 3. Ten day specimen illustrating the upward extension of the anterior pouch. FIGS. 4, 5, 6, 7, 8. Specimens illustrating but slight variation from the normal in size and contour.

serous portion of the blood clot occupied the central portion of the new joint space, extending upward to a point level with, or a little above, the articular cartilage of the femur. The organizing solid portion of the clot was adherent to the denuded anterior surface of the femur above, and a smaller clot occupied the fat pad area below. After the third day these clots rapidly decreased in size, and by the end of the tenth to the fourteenth day had almost entirely disappeared. By the third day a fibrinous exudate of varying thickness had been deposited upon all denuded surfaces. At first these surfaces appeared granular and blotchy, showing thin pink areas alternating with thicker, dark red patches. By the fourth to the seventh day these surfaces became smoother and began to lose their granular appearances, the color fading and translucent areas appearing. These translucent areas advanced as the thick, granular areas receded, until the entire denuded surface was covered by a translucent membrane of varying thickness. In some places this membrane covered striated bands of stretched out, underlying adhesions.

From the third to the seventh day both fine and rather coarse adhesions or fibrinous bands spanned the space between the denuded surfaces in the upper and lateral portions of the joint. At first these adhesions were so closely packed that they nearly obliterated the intervening space. Probably as a result of the absorption mentioned by Key, and the onset of motion in the joint, the finer adhesions disappeared entirely, leaving only the stronger bands which were apparently covered over with a smooth layer of surface cells. As a result of the absorption and stretching of adhesions, the capacity of the joint pouch rapidly increased, extending upward well above the condyles, and lateral to the femur. Almost without exception, dense adhesions persisted in the upper central portion of the newly formed pouch. These adhesions were attached to a rather thick but freely movable base adherent to the anterior surface of the femur, extending downward, in some cases, to the supracondylar notch. From this point they curved upward and forward, becoming continuous with the roof of the pouch, in the central line, just above the patella. It was observed that these adhesions persisted in every case which was permitted to progress beyond the twenty-eighth day. It was also noted that they were the direct cause of the typical sacculation of the upper portion of the new pouch into two rather definite lateral portions. Because of the attachment of these dense adhesions to the freely movable base of tissue on the anterior surface of the femur, they did not appear to interfere with the function of the joint in any way. Two other typical locations of persistent adhesions were noted. In twelve of the fourteen joints sacrificed after the second postoperative week, adhesions of varying size and strength extended from the newly formed infrapatellar fat pad area upward to the intercondylar notch. In five of these fourteen joints, adhesions of minor importance persisted between the denuded lateral condylar area and the lateral pouch wall on one or both sides.

*Fringes Overhanging Articular Surfaces:* It was observed that the surfaces of the articular cartilage were free from deposits of fibrin in most

cases. Occasionally fibrin deposits upon adjacent denuded areas assumed the appearance of overgrown granulation tissue, and in such instances these overhanging fringes encroached upon the articular areas. Of the twenty-one joints examined, in seven the patellar articular cartilage, in three the cartilage in the supracondylar region, and in one the lateral condylar margins were overlapped by fringes of this character. We also noted that, when the overhanging membrane remained unattached to the cartilage surface, that surface was not affected in any way; however, in those cases in which the fringes became adherent to the underlying cartilage, cartilage absorption of varying degree took place in each instance. Whether or not this was due to slight cartilage injury we were unprepared to say.

*Cartilage absorption* was noted most often in the region of the outer surface of the lateral condyles. In seven of the twenty-one joints examined one or both condyles showed cartilage absorption of varying degree. In three instances the patellar, and in two the supracondylar regions, evidenced these slight cartilage changes. They were undoubtedly due to the trauma incident to operation.

*Villous formation* was noted in three of the twenty-one joints examined. It was of typical cauliflower growth, approaching in size the head of a match. In dog number two, who had a fibrous union of the patella, one clump was found in the anterior portion of the intercondylar notch, and a second near the periphery of the right half of the patella. In dog number three there were small, indefinite, villous clumps overhanging the lateral surface of both condyles. In dog number four the clumps were numerous in the upper outer angle of the joint pouch. The distribution of these villous growths lead to the belief that they possibly were caused by long continued localized irritation, the result of faulty mechanics, as in the wide separation of the patella, or of injury to the articular cartilage and synovial membrane junction, incident to operation.

*Infrapatellar Fat Pad Regeneration:* The first forty-eight hours following operation the fat pad area was consistently occupied by a blood clot. During the next two or three days this clot gradually decreased in size, becoming paler and more friable. From the seventh to the fourteenth day the clot continued to shrink in size and appeared as a dense, grayish-brown, fibrous mass, which occupied but a small portion of the original fat pad area. During the third week it was noted that the new pad began definitely to increase in size, and by the fourth week a small zone of adipose tissue made its appearance in the central area of the dense fibrous pad. From this time on the new pad rapidly approached normal both in size and general appearance, except that the capsular layer of connective tissue was much thicker than normal. About the seventh day delicate thread-like adhesions were noticed extending from the upper portion of the clot to the intercondylar notch region. By the end of the second week these adhesions were larger and more noticeable, assuming the character of definite connecting bands. In all joints examined after the fourth week these adhesions persisted.

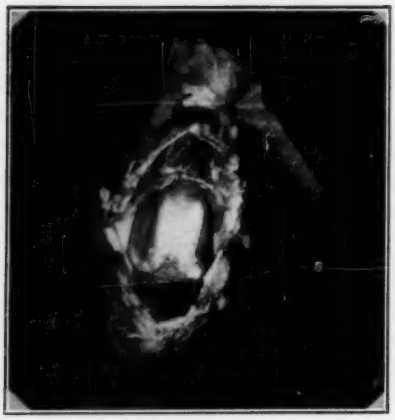

FIG. 9

Dog No. 11. Right knee—3 day specimen.

FIG. 10

Dog No. 17. Left knee—7 day specimen.

FIG. 11

Dog No. 12. Right knee—10 day specimen.

FIG. 12

Dog No. 10. Left knee—49 day specimen.

FIG. 13

Dog No. 9. Right knee—89 day specimen.

FIG. 14

Dog No. 7. Left knee—108 day specimen.

Photographs of knee joints of dogs, which have been operated on, illustrating various stages of their regeneration.

## MICROSCOPIC METHOD AND STUDY

The material for histological study was uniformly fixed in a 10 per cent. formalin solution. Small blocks were removed from the fixed material and cut by the paraffin method to a thickness of 6 microns. All sections were stained by Ehrlich's haematoxylin and eosin. The results which were obtained in this study closely parallel those reported by Key. He has reported from his studies that in the rabbit the normal synovial membrane was composed of a single layer of cells. In our material obtained from dogs it would be impossible to follow a single layer of these superficial cells, and for this reason we have looked upon the lining of the pouch as composed of several layers of more specialized cells bound together by fibrillae. These surface cells, presumably of fibroblastic origin, were spindle-shaped, and rather densely packed. They arranged themselves in irregular fashion, some lying directly on the surface, others partly on the surface, while still others lay definitely at a deeper level but sent their processes to the surface. For this reason we have considered the synovial membrane as composed of three or four levels of superficial, specialized cells. Beneath this layer was a loose areolar tissue bearing many small blood vessels (Figs. 15 and 16).

Immediately following operation, the denuded surface was covered by a blood clot. The red blood cells tended to disappear quickly from the clot and at twenty-four hours a thick, adherent layer of fibrin remained, in which were scattered a few red blood cells and a surprisingly large number of polynuclear leucocytes. But few lymphocytes and large mononuclear cells were present at this stage, and no fibroblasts were found (Fig. 17).

By the end of three days much of the fibrin had been dissolved and the lymphocytic and phagocytic cells were present in about equal numbers. In the tissues just beneath the fibrin deposit the fibroblastic cells were becoming swollen and their nuclei more chromatic. As yet there was no extension of fibroblasts into the fibrin layer (Figs. 18 and 19).

By the tenth day the newly formed fibroblastic cells had extended into the fibrin layer; the phagocytes had entirely disappeared, and but a few scattered lymphocytes remained. The surface layers of fibroblasts were somewhat denser than the underlying ones. About this time we noticed that many new capillaries had invaded the loose underlying fibroblastic tissue (Fig. 20).

In the 14 day specimen the denuded muscle was completely covered by a thick layer of fibroblasts. Their hyperchromatic, oval nuclei were swollen, and mitotic figures were frequent. There was no fibrin, neither were there leucocytes present. There were many new capillaries scattered about the underlying area. The surface cells appeared to be slightly more compact.

After the fourth week the deeper fibroblasts were shrinking in size and rapidly assuming the characteristics of normal fibrous tissue cells. The surface layer was smooth, the cells being smaller and flattened,

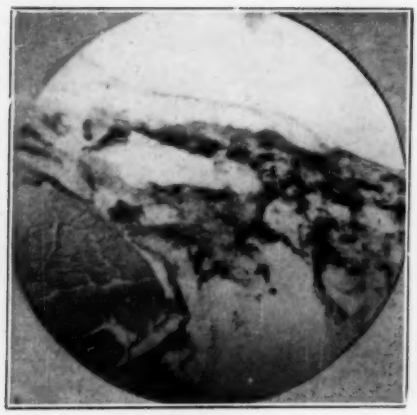

FIG. 15

Normal specimen; × 100.
Showing relationship between synovial layer and underlying structures.

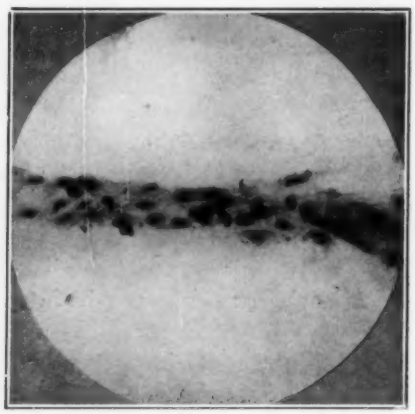

FIG. 16

Normal specimen; × 430.
A portion of synovial membrane showing the "cobble-stone" arrangement of cells.

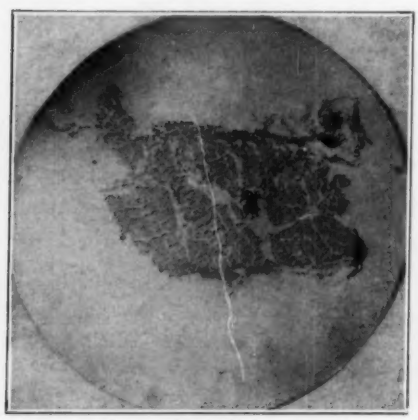

FIG. 17

24 hour specimen; × 50.
Synovial membrane absent. Denuded surface covered by fibrin and phagocytes.

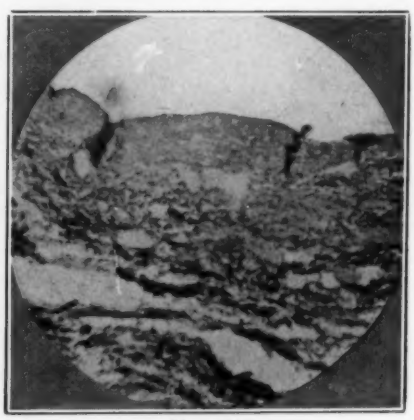

FIG. 18

3 day specimen; × 100.
Thick deposit of fibrin on denuded surface. No fibroblastic invasion of fibrin layer.

Photomicrographs of Recovered Specimens Illustrating Various Stages of Regeneration of Synovial Membrane.

resembling more closely the cells of normal synovial membrane. The newly formed fibrous tissue zone was becoming less vascular. Between this layer and the muscle area there was apparently little or no attempt at areolar tissue formation (Figs. 21 and 22).

In the 108 day specimen the synovial membrane was practically undistinguishable from that of the normal animal. The tissue was no more vascular than normal and there was only a feeble attempt to replace the subsynovial areolar tissue.

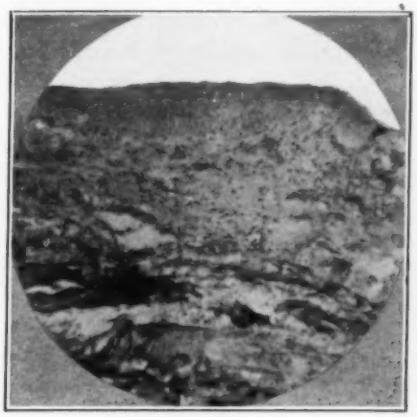

FIG. 19

3 day specimen; × 430.
Higher magnification of fibrin deposit shown in Fig. 18. Demonstrates the invasion of the fibrin layer by many phagocytes and lymphocytes.

FIG. 20

10 day specimen; × 100.
Invasion of fibrin layer by fibroblasts. Formation of many new capillaries along muscle margins. New capillaries invading deeper fibroblastic layers.

FIG. 21

31 day specimen; × 100.
Muscle margin covered by a layer of fibroblastic cells. Points of irregularity on surface suggest attachment of absorbed adhesion.

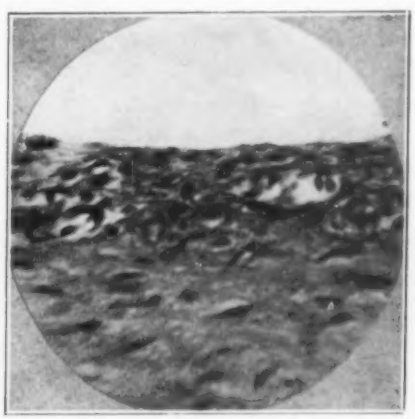

FIG. 22

31 day specimen; × 430.
Higher magnification of Fig. 21 showing new synovial membrane regeneration. Fibroblastic surface cells more compact and less hyperchromatic. Well formed capillaries present. No evidence of subsynovial or areolar tissue layer.

Photomicrographs of Recovered Specimens Illustrating Various Stages of Regeneration of Synovial Membrane.

A study of the specimens between the 28th and the 108th days showed very little change except that the newly formed fibroblastic area progressively approached the normal in appearance.

It is highly significant to note that the new synovial membrane in thirty days has, in histological appearance, very closely approached the

synovial membrane in the normal joint. The phase of hyperplasia having repaired the injury, further cell growth is checked. The replacement of joint fluid, the increase in weight-bearing and the resumption of joint motion probably all share in checking further purposeless hyperplasia in the membrane. The changes noted histologically prior to four weeks are those of regeneration of the surgically excised synovial membrane. Subsequent to this time, the changes are only those of cell ageing, and maturity into inactive fibrous tissue. This histological fact is in perfect clinical harmony with the recorded observations concerning the activity of the animals, and their freedom of joint motion after the first four weeks.

## CONCLUSIONS

1. Synovial membrane does regenerate after typical synovectomy.
2. The regenerated pouch closely simulates the normal in size, contour, histological structure and function.
3. The newly formed pouch is the result of connective tissue metaplasia.
4. Connective tissue metaplasia is progressive until about the fourth week when the synovial membrane has been reformed. With this completed, the stimulus for new growth is removed and the fibroblastic cells mature into normal connective tissue.
5. That there is an inhibition of progressive metaplasia after the new synovial membrane is formed, explains the absence of excessive scar tissue formation as well as the permanency of restored function.

I wish to make particular acknowledgment to Dr. Earl Rice, St. Louis, Mo., for assistance and valuable suggestions in the carrying out of the details of this work; to Dr. Ralph R. Simmons, Pathologist at the Iowa Methodist Hospital, for help in the preparation and study of specimens and to the Sisters of Mercy at Mercy Hospital, Des Moines, Iowa, who made this work possible.

## REFERENCES

1. SWETT, P. P.: Synovectomy in Chronic Infectious Arthritis. J. Bone and Joint Surg., V, 110, Jan., 1923.
   SWETT, P. P.: Synovectomy in Chronic Infectious Arthritis. J. Bone and Joint Surg., VI, 830, Oct., 1924.
2. JONES, E.: Synovectomy of the Knee Joint in Chronic Arthritis. J. Am. Med. Assn., LXXXI, 1579, Nov. 10, 1923.
3. SPEED, J. S.: Synovectomy of the Knee Joint. J. Am. Med. Assn., LXXXIII, 1814, Dec. 6, 1924.
4. STEINDLER, A.: Synovectomy and Fat Pad Removal in the Knee Joint. J. Am. Med. Assn., LXXXIV, 16, Jan. 3, 1925.
5. KEY, J. A.: The Reformation of Synovial Membrane in the Knees of Rabbits after Synovectomy. J. Bone and Joint Surg., VII, 793, Oct., 1925.

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# CONGENITAL MALFORMATION OF SPINE*

BY CHARLES W. PEABODY, M.D., DETROIT, MICHIGAN

The following case is reported, not as presenting an unusually rare condition, but rather on account of the extent and variety of the developmental defects combined in this one spine. These include multiple rachischisis, sacralization of the fifth lumbar, fusion of adjoining centra, rudimentary centrum, unilateral defect of two posterior elements including corresponding ribs, and peripheral fusion of ribs.

The patient, H.F., 30720, was first observed at the clinic July 30, 1923, in the Division of Pediatrics, where he was brought for examination on account of curvature, and referred thence to this Division for disposition. A family history negative for stigmata of lues or tuberculosis was obtained. The boy was the only child, a delivery at full term but with instruments after fifty hours' labor; required no resuscitation and weighed seven and three-quarters pounds. The child was breast fed for twelve months, and seemed to have no feeding difficulties; had a fairly well balanced diet including one quart of milk daily, orange juice but no cod liver oil. Development was not unusual; he sat alone at ten months and was said to have stood alone soon after. Bladder and bowels were under control at twelve months. Child walked at sixteen months and put words together at eighteen months. Date of fontanelle was not known. Dentition began at eight months and first set had just been completed. Weight at examination was 26.2 pounds. Rubeola at eight months but no other diseases and no upper respiratory or ear disorders.

History of complaint was given as follows: Child was reported normal in every way at birth by attending physician. Mother, suspicious about back, called a physician at two months, who found a curvature present but predicted no increase. For last eight months mother has felt curvature was increasing.

The routine physical examination brought out no findings of importance outside of spine. Routine urine analysis and blood Wassermann tests were negative. Hgb. was 80 with WBC. of 8,300 and nothing important was shown in differential. Showed negative reaction to tuberculin.

At the orthopaedic consultation, the following notes on the physical examination appear in the record: child apprehensive but handled without obvious discomfort; no protection or splinting of back; stoops and bends at will. Examination shows, as most striking feature of the appearances, a very sharp lateral deviation in mid-back centering about the tenth dorsal, convex to right. This seems to be the important major curve with diffuse compensatory curves both above and below. The thorax bulges posteriorly to the right, and it is flat or concave to left of the major curve. There also appears a significant growth of hair over lower dorsal spine and a smaller amount lower down. Here, about mid-lumbar, is a moderate prominence or kyphosis about the level of the second or third lumbar segments. The amount of lateral compensability of the spine can be increased by manipulation but there seems to be fixation of the lower dorsal segments. There is no local tenderness, increased muscle tone or apparent pain on manipulation, including hyperextension. A clinical impression of deformity arising on developmental anomalies was sustained by the subsequent x-ray studies.

The x-ray negatives which included the entire dorsal and lumbar spine on single

*From The Orthopaedic Division, Department of Surgery, The Henry Ford Hospital, Detroit.

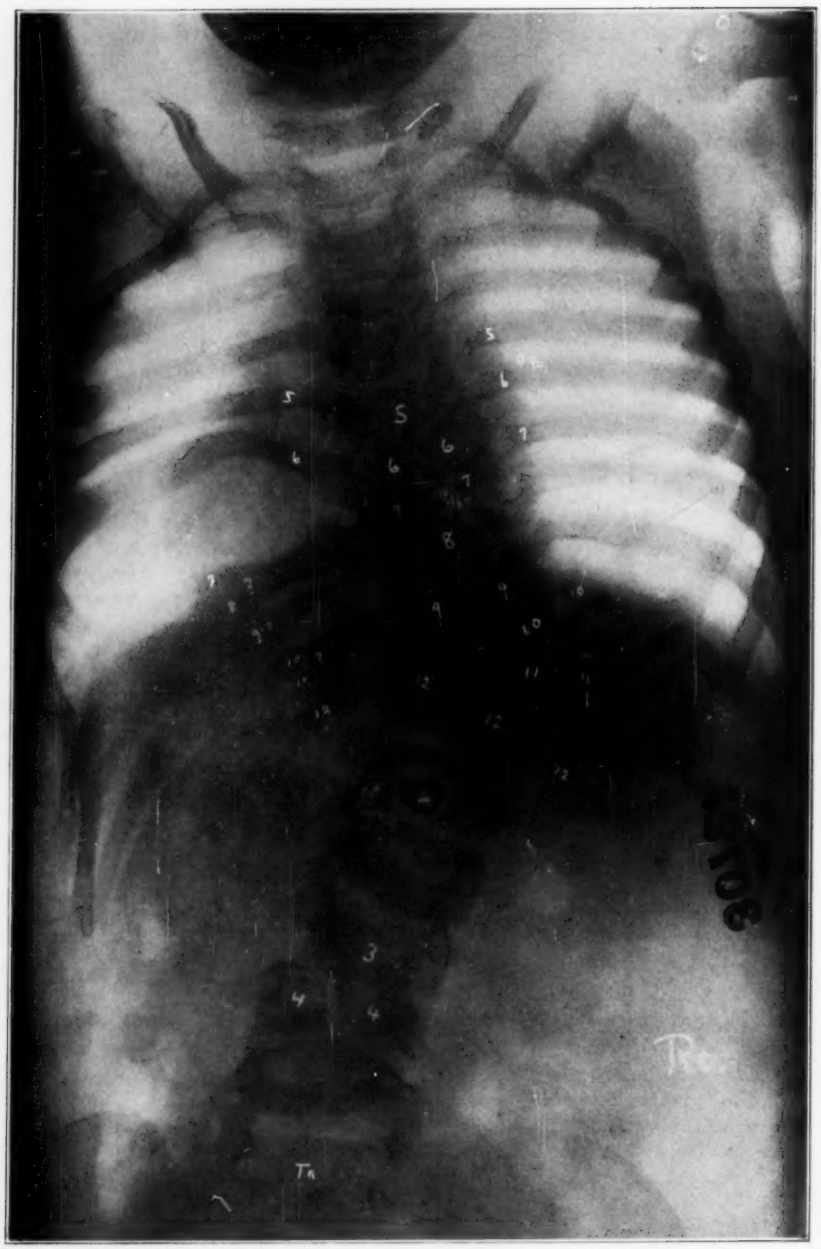

FIG. 1

See detailed description in text. The segments have been numbered with corresponding ribs, the tenth and eleventh being deficient on their left sides. Note extensive intercostal space above fused ribs on left. Suggested fusion of third and fourth vertebrae is confirmed in lateral view. Apparent sixth lumbar segment is marked transitional as sacral segments cannot be identified.

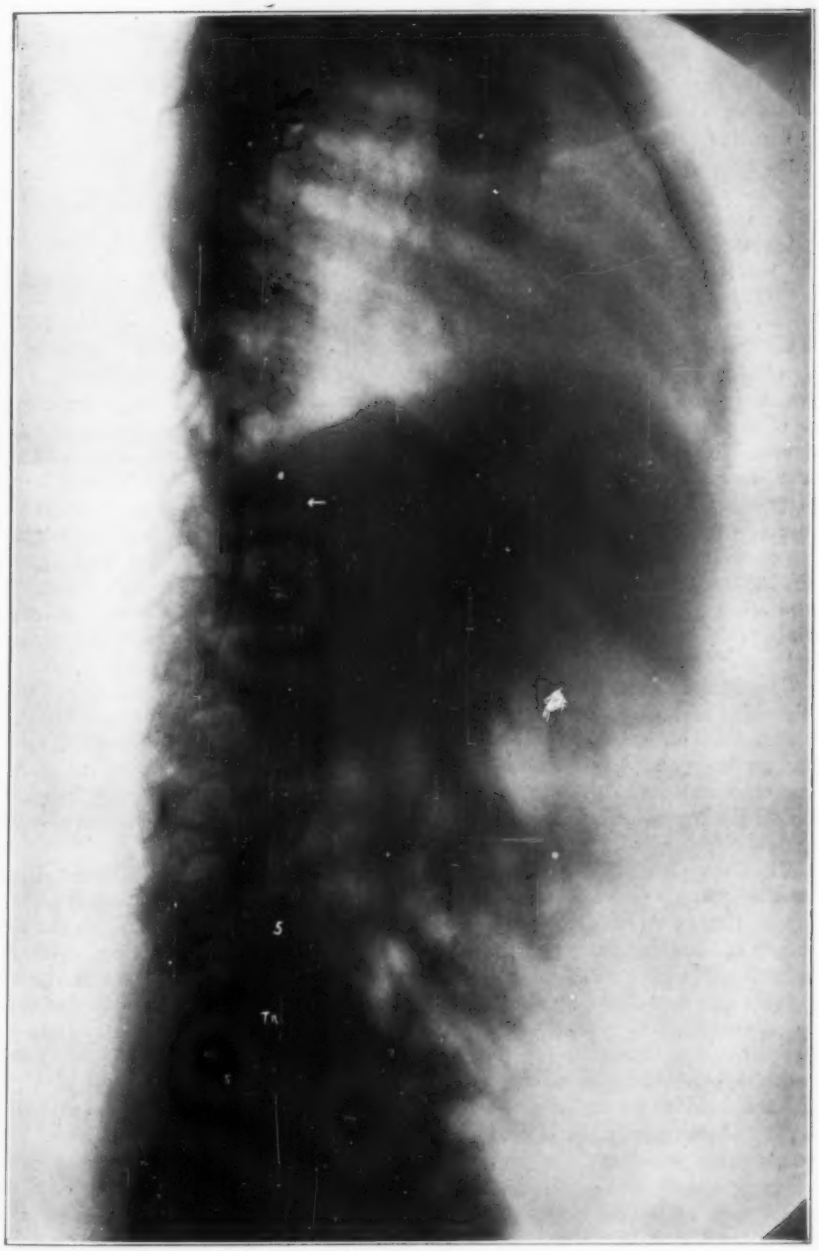


FIG. 2

Note fusion of fourth and fifth lumbar. Arrow above points to a very small wedge-shaped rudimentary centrum which corresponds in level to incomplete masses marked 10 and 11.

films, in anteroposterior and lateral positions, were studied with great interest. The detail was very satisfactory in the originals, but inevitable difficulty of reproduction in so small an individual would seem to warrant minute description of the various findings in the text.

At the sacrolumbar juncture there seemed to be a transitional segment with large lateral masses apparently free from the sacrum but articulating with the ilia. Above this five lumbar segments can be seen, the posterolateral masses being normally developed and fused save at the fourth. Here there is a cleft between the laminae and in addition the posterolateral mass on the right appears to be fused with that of the segment above. (See note on findings in lateral view at this level.)

On the right side there are twelve ribs of normal appearance. Each articulates in some way with a posterolateral mass. The masses corresponding, however, to the tenth and eleventh ribs on the right, are rudimentary and have no counterpart on the left side, and all segments from six to twelve are cleft in varying degree. On the left side the first six ribs seem not abnormal save that the last is rather large. Below it the intercostal space is several times the normal width. At the site of what should be the lower six ribs is a mixed-up and more or less fused mass, giving something of the appearance of an anastomosing nerve plexus. About the mid-scapular line there is a complete intercostal fusion of all. Peripherally the elements of six radicals can be counted but nearer the spine only four. The uppermost is abnormally large with a large lateral process, while the next below is almost rudimentary. The third down is larger and seems to bifurcate just before merging in the fusion of all. It articulates with the lateral mass of the ninth segment, while the last rib element articulates with that segment adjoining the lumbar spine and corresponding to the opposite last rib, i. e., the twelfth dorsal vertebra, these two, the ninth and twelfth, making the apex of the angle of lateral deviation, the two rudimentary masses for the tenth and eleventh ribs of the opposite side lying opposite on the convexity of the deviation.

The lateral film shows additional abnormalities. In the lumbar spine the centra of the third and fourth segments are fused, with a little kyphos at this point. The transitional segment, lying below the iliac crests, has a full-sized disc beneath it, and is either an interpolated segment or a lumbarized first sacral. Just above the twelfth dorsal centrum is an indistinct mass showing a defect anteriorly and probably indicating rudimentary centra attached to the posterolateral masses for the tenth and eleventh ribs right.

That the physical deformity was progressing and would probably so continue seemed reasonably certain. Correction of deformity most certainly was impossible and compensation to be obtained by brace and exercise treatment seemed to be the aim. Analysis of the roentgenograms seemed to indicate that while the vertebral deformity involved only the segments nine to twelve, compensation was prevented in the two adjoining segments above by the fusion of ribs. The parents were advised accordingly that an operation to release the seventh and eighth ribs might aid considerably the subsequent work, and this they accepted. At operation resections in the fused mass were done, establishing an intercostal space between the seventh, eighth and ninth rib elements. This was attended with some difficulty, as it was found impossible to separate the parietal pleura from the anterior periosteum, and the chest had to be opened. The accompanying pneumothorax proved slight in degree, and carried no postoperative complication, convalescence being uneventful. Postoperative treatment included lateral bed traction, corrective casts and braces but at end of six months x-ray showed re-establishment of bony fusion between the ribs. The child was continued in a scoliosis brace of the Klein type, with exercises and manipulations.

About a year after admission a new complication developed in the treatment. The child began to complain of hypersensitiveness in the hairy area over the lower dorsal segments, would not lie on his back or allow anyone to touch him at this point, finally complaining constantly even of pressure of clothing. Examination showed a soft swelling in mid-line and an area of acute hyperaesthesia about size of a half dollar. Diagnosis

was made of meningocele or aberrant nerve, and operation advised and accepted. An elliptical excision of skin and subcutaneous fatty tissue was made, revealing a small pedicle coming through the spinal cleft. In it was one nerve about the size of a pencil lead. Traction was made on this, injection with a few drops absolute alcohol and division; deep fascia overlapped and rest of wound closed in two layers. Convalescence was uneventful. In this operation as well as in the first, the cooperation of Dr. R. D. McClure, Surgeon-in-chief, should be acknowledged.

Since operation there have been no further subjective or objective neurological symptoms. Treatment of deformity by brace and exercises has been confirmed. The lateral deviation seems less noticeable on the surface and the posterior bulging of the right thorax seems less. On the other side the flattened area, corresponding to the fused ribs, remains unchanged. Recent x-rays show no change in spinal alignment, but the intercostal space above the fused ribs seems to have increased, absolutely and relatively. In general health and growth the child seems to be developing normally and no abnormal symptoms have appeared in the lower extremities.

# A PLASTIC FLAT FOOT OPERATION

BY OSCAR LEE MILLER, M.D., CHARLOTTE AND GASTONIA, NORTH CAROLINA

The management of the so called static flat foot has been a problem confronting the orthopaedic surgeon since the beginning. Many procedures, including operations, special exercises, braces and shoes, have been offered from time to time to meet the need of the flat or relaxed lateral arch of the foot. So large has been the contribution to the treatment of this entity, and so satisfactory to some may be these methods of treatment, that one almost hesitates to bring forward another suggestion. However, there is here described a simple plastic operation, proven useful for a certain type of flat or relaxed foot, and several cases are shown in which the operation has been used successfully and the results tested by time and the normal use of the foot.

In the routine of the clinic or private practice, there are presented a considerable number of cases of flat or relaxed foot in the adolescent or pre-adolescent child. No one has ever described the etiology of these cases to complete satisfaction. These children may seem to show this pathology alone, but on careful examination usually they will be found not up to par in other ways. They may show poor posture generally, an anaemia, a listlessness, or a number of conditions usually spoken of as minor ailments. In short, there is something basicly weak about the child whose feet are relaxed, tired, painful on exertion, and finally anatomically flat, if not properly managed through the growing period.

It is not the purpose of this paper to go into the medical management of such patients, but there has been inferred already a medical aspect which really exists in most of these children and which must be met intelligently, if full duty is done. The relaxed foot, in its discomfort, its uncomeliness and its potentialities, is the problem primarily dealt with here. In passing, however, serious thought should always be given to the fact that there are conditions to consider in every case besides the feet. Many of these patients have some metabolic deficiency akin to that seen in rickets.

There can be no dogmatic classification of so called flat foot. Relaxed foot is a better term and more nearly describes the condition of the feet in children. A foot may appear anatomically flat, but is correctible with slight force. In the very small child there is a relaxed foot condition very disturbing to mothers, but this type of foot usually improves satisfactorily with normal growth and development. The extreme flat foot, the rigid and spastic flat foot, belong more generally to later life and their management is another problem. One cannot take the liberties in plastic operations on the adult foot that can be taken with the foot of a child.

As these flat foot patients present themselves with their varying

degrees of arch relaxation, one mentally classifies them as to the method of treatment offering best results. Some may respond to simple corrective shoes, some will need only foot exercises and special shoes, while others will need stretchings, casts, etc., to give them improved posture and added strength. Then the period of observation of the patients must be of sufficient duration to see that they use the feet properly to maintain permanently the correction after it has been gained.

FIG. 1

Sketch, anterior view, of a slightly accentuated adolescent flat foot with incision exposing the inner aspect of the mediotarsus.

Fortunately, the measures referred to will really meet the needs of the majority of the relaxed feet in growing children during or near the adolescent period. However, there are some distinct exceptions and it is to these exceptions that this operative procedure is addressed. One may tell instinctively the feet needing operation as they come under observation, or one may try the milder measures on all feet and demonstrate that only by a radical operation can a certain obstinately relaxed foot be competently corrected.

The foot requiring operation has usually been gradually depressed along the lateral arch for many months or years. The weight lines are off. It may or may not be symptomatic. It soon mis-shapes the shoe and is noticeably uncomely. Practically always the heel cord is pathologically shortened. The patient cannot voluntarily carry the foot into complete adduction. All structures on the inner aspect of the tarsus and mediotarsus are stretched and relaxed, especially the tibial tendons and the calcaneoscaphoid ligament. The head of the astragalus is directed inward in varying degrees, and the scaphoid is prominent. The foot is almost flat. The patient or the family is discouraged over it.

Such a type of foot as has been briefly described may be treated in the gymnasium by proper exercises, may be fitted with special shoes and

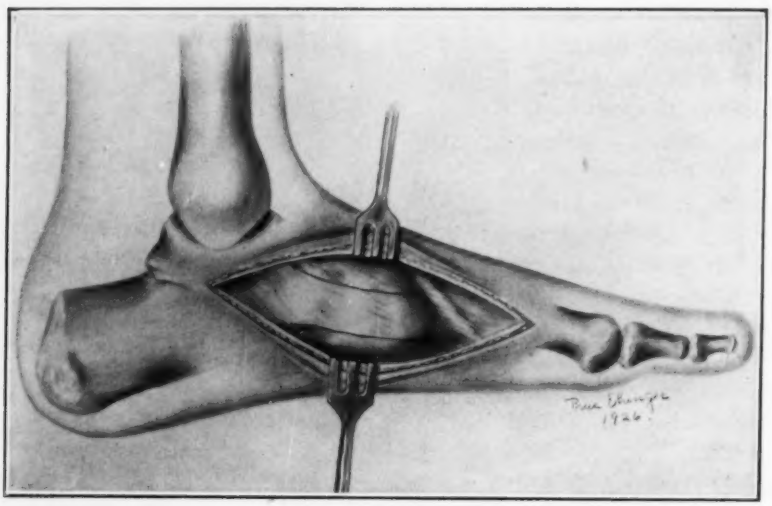

FIG. 2

Marking out the figure in the fascia to be lifted up with slab of bone beneath.

arch supports, and apparently may be improved, but when active treatment is abandoned, however long it has been kept up, the foot will assume a relaxed flat posture with all its potentialities of later pain and uncomeliness. These feet should be corrected by operation.

The operation offered and described here is simple and can be done in a short time. The local structure disturbance is moderate and the convalescence reasonably rapid. Both feet can be operated on at one time.

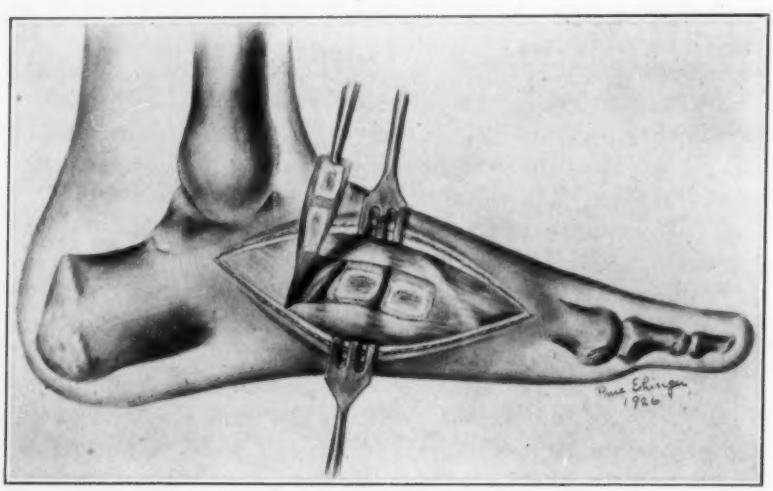

FIG. 3

Showing fascia dissected up with slab of bone from side of scaphoid and internal cuneiform bones.

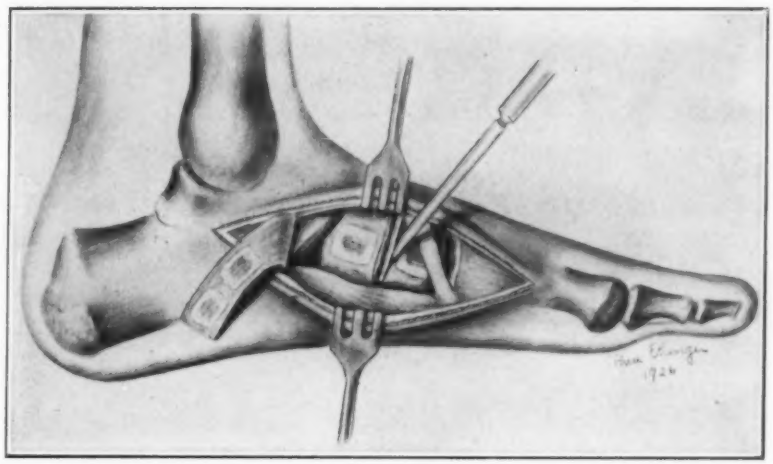

FIG. 4

Excising articular cartilage between scaphoid, internal cuneiform and base of first metatarsal bones. The insertion of the anterior tibial tendon is not disturbed.

The approach incision is made along the inner side of the tarsus and the mediotarsus from behind, at a point over the os calcis, forward over the bodies of the scaphoid and internal cuneiform bones and ends at the base of the first metatarsal. This opens right down on the spread of the calcaneoscaphoid ligament and the insertions of the posterior and anterior tibial tendons. These structures are on an exhausted stretch and the ligaments thinned out. The strong normal cartilaginous consistency of the calcaneoscaphoid ligament is not so evident.

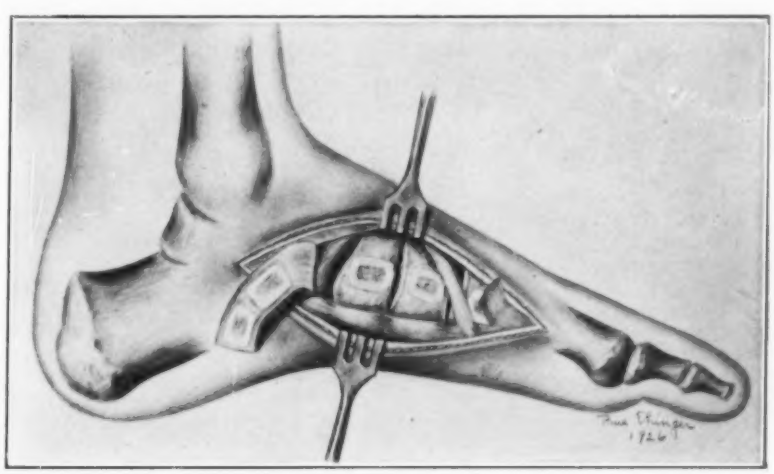

FIG. 5

Shaping up the foot by rotating the forefoot and carrying it into adduction. Note the slab of bone lifted with periosteum from side of first metatarsal.

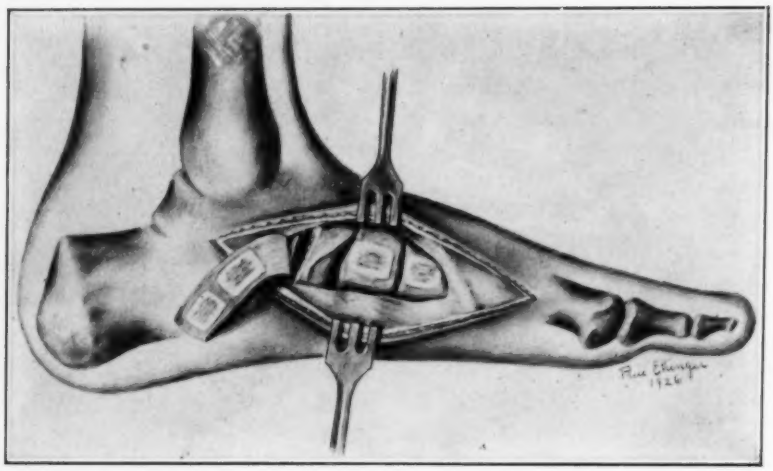

FIG. 6

Showing section from neck of astragalus. This can be done through the incision when necessary.

After the subcutaneous fascia and fat are dissected up, a sharp chisel or osteotome is taken and the fanned-out insertion of the calcaneoscaphoid ligament and posterior tibial tendon is lifted on a thin slab of bones from attachment to the sides of the scaphoid and internal cuneiform bones and held back by a retractor. This exposes the joints between the astragalus and scaphoid, scaphoid and internal cuneiform, and internal cuneiform and base of the first metatarsal bones. The lesser articular ligaments are lifted

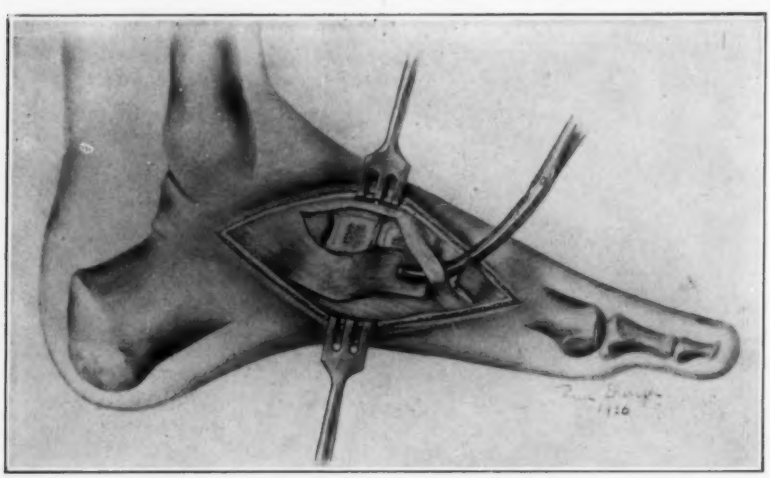

FIG. 7

Drawing the fascial sling and slab of bone forward to be stitched tautly to the side of first metatarsal bone. The slab of bone, when the fascia is drawn taut, should fall across the joint spaces and act as a graft.

upward and downward, subperiosteally, and preserved as well as possible to re-apply over the area of fusion. This leaves these small joints exposed and the articular surfaces from between the scaphoid and internal cuneiform, and internal cuneiform and head of first metatarsal are lifted out with a thin osteotome. The heel cord is lengthened at the same time.

The osseous changes on the inner aspect of the foot vary with the age of the patient and with the deformity. In cases of long standing the head and neck of the astragalus have grown appreciably longer and the point of the scaphoid is hypertrophied on its inner aspect. In such a case (though such cases are not so frequently seen) one can shorten the neck of the astragalus by taking out a section with the osteotome. The head can then be transplanted toward the middle of the foot, thus placing it more within its articulation with the scaphoid.

It should be stated that a part of the pathology in these feet is a widening of the spaces between the inner margins of the tarsal and mediotarsal bones. When the articular surfaces are removed, as described, this allows the forefoot to be brought into adduction and the first metatarsal rotates to a corrected position. When this is done, the foot is held in adduction and the slab of bone holding the insertion of the calcaneoscaphoid ligament and posterior tibial tendon is pulled forward on tension and transplanted as a graft to the body of the internal cuneiform bone and base of the first metatarsal. This whole mass passes forward beneath the anterior tibial tendon, which is not disturbed at its insertion. The wound is closed layer by layer, using chromic catgut beneath, and silk in the skin.

In this procedure the scaphoid, internal cuneiform and base of first metatarsal fuse to maintain their corrected relations. The broad insertions of the calcaneoscaphoid ligament and posterior tibial tendon have their slack taken up as they are transplanted forward, and this forms a substantial

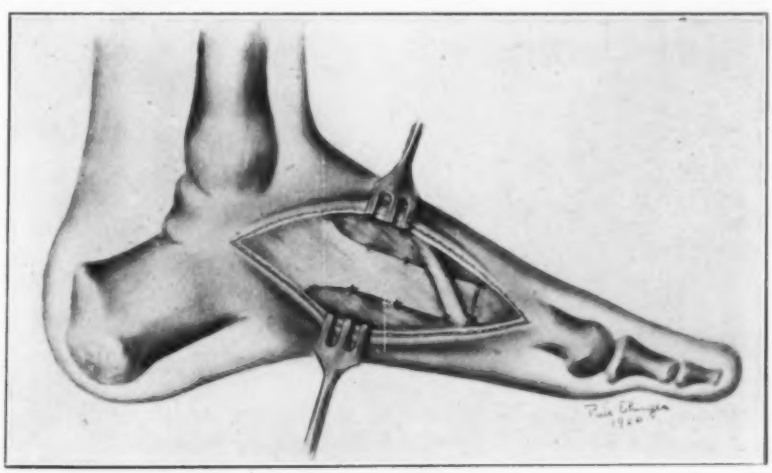

FIG. 8
Showing the fascia sutured in place maintaining a normal arch line.

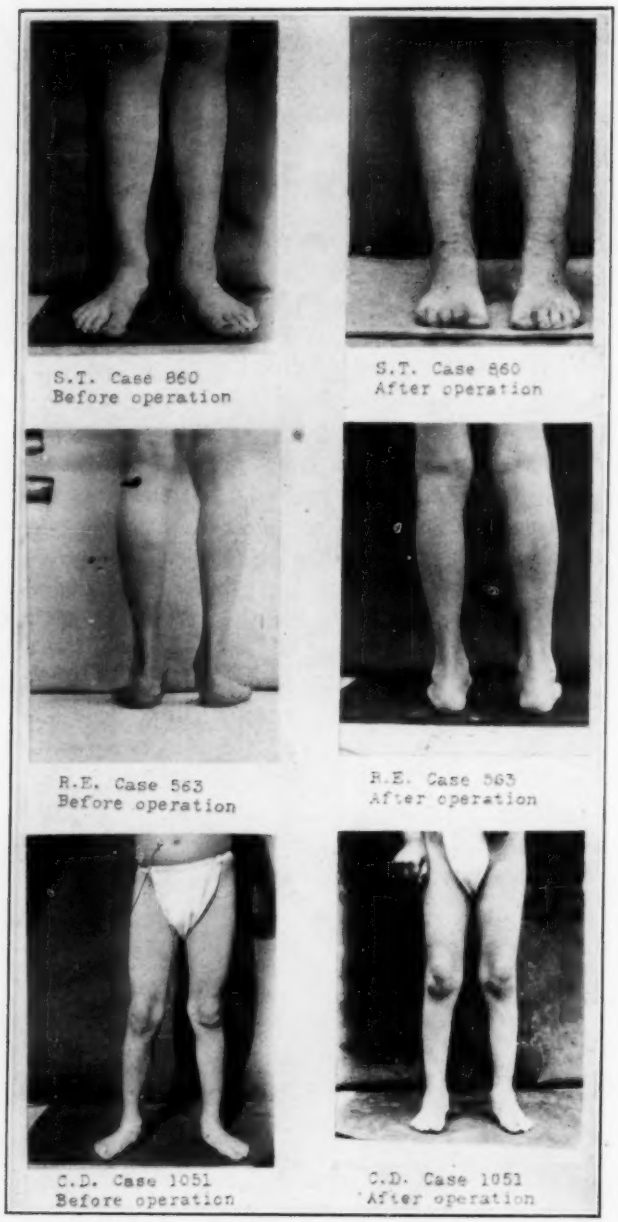


FIG. 9

thickened sling to keep the head of the astragalus directed into the normal weight-bearing lines of the foot. A very normal looking lateral arch is established.

After the operation the foot is carried six weeks in plaster and then put into an adducting shoe with a Thomas heel. A short period of foot

exercises and massage is instituted, and the child begins supervised weight-bearing immediately. The convalescence is sufficiently rapid and the sensitiveness of the foot is in proportion to any plastic foot operation. A light metal arch support was used for a while in some, but not all, of the cases operated upon.

We have used this procedure with satisfaction on sixteen feet during the past two and one-half years and have seen them recover from any laming effects of the operation, maintain their correction and walk comfortably with a sustained arch.

Patients have been of both sexes and the average age at time of operation was twelve years. The operation does not seriously interfere with further bone growth, as only the articular surfaces are removed. If the foot selected is in the adolescent period, it has already attained its major growth.

## SUMMARY

1. Some relaxed feet in the pre-adolescent and adolescent child must be operated on to obtain permanent correction.

2. The operation described is simple, short and effective.

3. The feet operated upon have stood all normal tests to demonstrate the permanency of their correction.

# AN OPERATIVE PROCEDURE OF VALUE IN THE CORRECTION OF BOWED TIBIAE

BY R. I. HARRIS, M.D., TORONTO

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The success of operative procedures upon bone is often dependent upon refinement of technique. In no other field of surgery is attention to minutiae so important and so essential to a happy outcome. The rigidity of the tissue being operated upon and the limitations to its reparative powers, necessitate its section, refitting and fixation with such care and accuracy as a cabinet-maker uses in his trade. Frequently the most carefully planned operation for the correction of bony deformity falls short of success because it fails to provide for the adjustment of the bony fragments in their new position with that accuracy which is so essential to sound union. Intimate and extensive contact of the fragments, with provision for complete immobilization, must be obtained in order to assure maintained correction of the deformity, solid union, and ultimate good function.

In few conditions are these requirements more conspicuous than in the deformity of bowed tibia, particularly that form which may occur in adults after fracture of the tibia without fracture of the fibula. In such cases, should union occur with overriding of the fragments, or should there be loss of substance from the shaft of the tibia as the result of sepsis, the resultant shortening of the tibia without alteration in length of the fibula produces marked angulation of the limb at the site of fracture. This deformity is extremely disabling because of the alteration it produces in the line of weight-bearing, with consequent abnormal strain upon ankle and knee joints. Its correction is dependent upon means which will lengthen as well as straighten the tibia. But as many cases occur in adults, and in a bone in which non-union is notoriously prone to occur, the operative procedure must be one which will not only maintain the length of the bone, but will also insure adequate contact and firm fixation of the fragments; desirata somewhat difficult of attainment.

The operation here described fills the needs of such cases. The diagrams indicate with sufficient clearness the various steps. The tibia is cut through obliquely, slightly above the level of the deformity (Fig. 1). The superficial surface of the bone is cut as deeply as possible with a motor saw, and the section completed by means of a thin osteotome. The line of the oblique section is best made so that the apex of the lower fragment lies on the convex side of the deformity; or expressing it in another fashion:—the line of section runs from the convex side downwards and inwards. When the bone has been completely cut through, correction of the angular

deformity will at the same time result in lengthening of the tibia, since the lower fragment swings through an arc of the circle whose centre is the head of the fibula (Fig. 2). This separates the fragments at the line of section. To secure contact of the fragments in their corrected position a notch is cut in the upper fragment, into which the apex of the lower fragment is fitted. The success of the operation is dependent, to a considerable degree, upon the accuracy with which this notch is cut. It should always be cut with a motor saw, and never with an osteotome, since the latter is prone to break the cortex at some essential point. The apex of the notch should be slightly lower than the highest point of the lower fragment so that the two fragments, when fitted, will be pressed firmly together by the pull of the soft tissues. One side of the notch is vertical to fit the cortex of the outer side of the lower fragment. The other side is cut off obliquely to the tip of the upper fragment. This surface then fits the cut surface of the lower fragment. In order to fit the pointed lower fragment with notch prepared for it, it is necessary to displace it medially. If the amount of the medial displacement is considerable, it may be necessary to free the upper end of the lower fragment by subperiosteal stripping. Once in place, the fragments

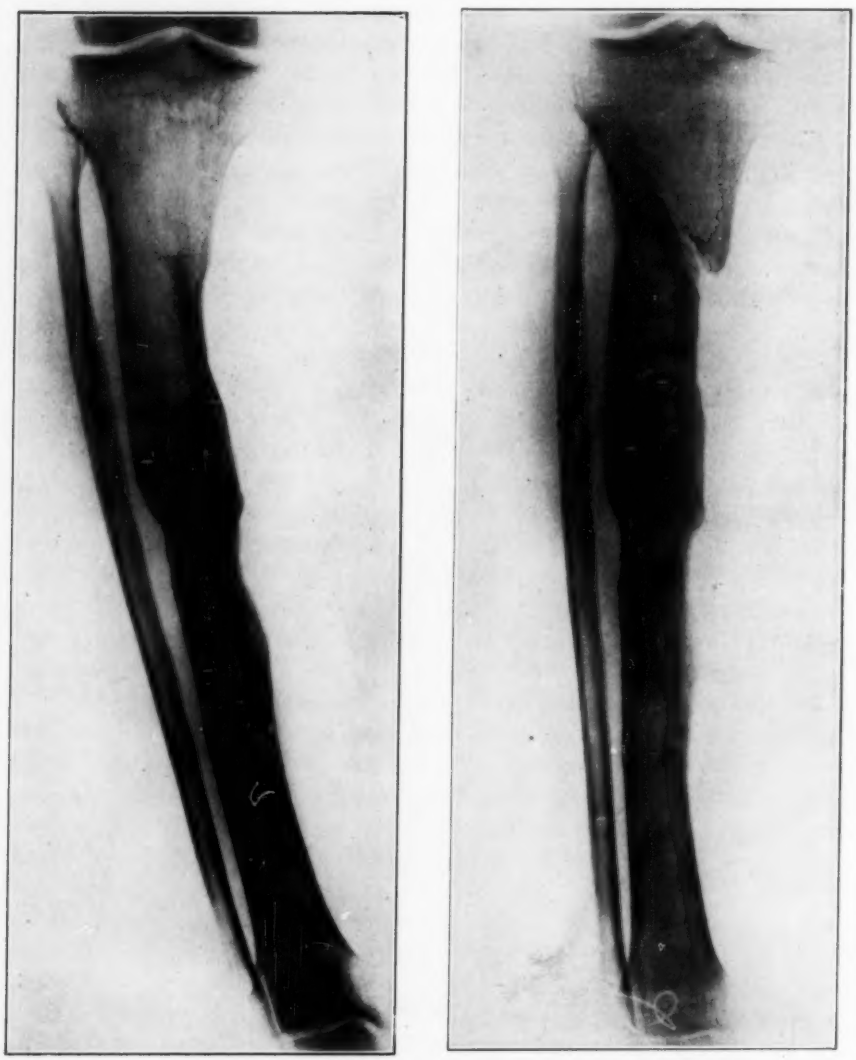
FIG. 1. The line of section through the deformed tibia. Drawn from a radiogram.

FIG. 2. The correction of the angular deformity after section of the tibia results also in increased length of the leg.

FIG. 3. The pointed lower fragment fitted into the notch prepared for it in the upper fragment. The reduction of the deformity is then self-retaining, and intimate contact of raw bone surfaces is provided.

are firmly fixed, and the correction of the deformities of angulation and shortening is perfectly maintained. Extensive and intimate contact of raw bone surface is also provided, so that union is certain.

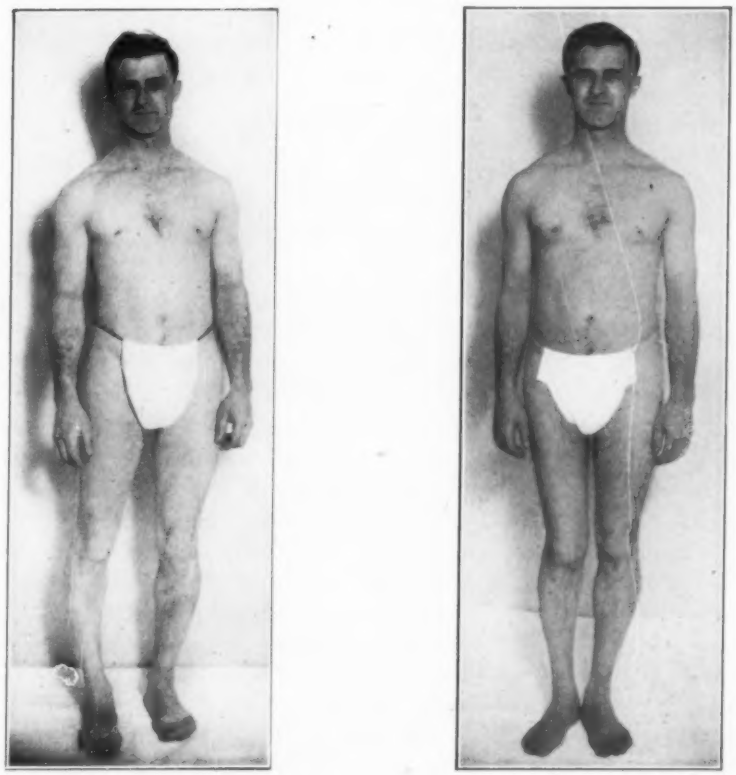
I have used this operation with great satisfaction in the correction of the angular deformities of the tibia which ocurred in soldiers following gunshot wounds of the tibia (Figs. 4 and 5). It has been used also in the correction of severe rachitic bow legs of children. In the latter, the torsion



*A* *B*

FIG. 4

Radiographs of bowed tibia due to gunshot wound, treated in the manner described.



*A* *B*

FIG. 5

Photographs of the patient whose radiographs are shown in Fig. 4—*A* before, and *B* after operation.

of the tibia, which is frequently present, necessitates trimming of the upper end of the lower fragment in order that the planes of the cut surfaces may be parallel after the rotation deformity has been corrected. With this precaution the operation is equally satisfactory in these cases.

# THE RÔLE OF THE CAPSULE IN JOINT CONTRACTURES: WITH ESPECIAL REFERENCE TO SUBPERIOSTEAL SEPARATION*†

BY DAVID SILVER, M.D., PITTSBURGH, PA.

About five years ago subperiosteal separation of the proximal dorsal attachment of the capsule of the metacarpophalangeal joint was performed subcutaneously for the relief of extension contractures of the four fingers. Some time later the attempt was made to apply the same procedure in flexion contracture of the knee but it was unsuccessful because, as is now believed, the distal instead of the proximal attachment was attacked. The procedure seemed to possess such obvious advantages that a study of the part played by the capsule in the various types of joint contractures and the applicability of subperiosteal separation in their correction was begun. It soon became evident that but little attention had been paid to this factor in deformity and that considerable experimental work would be necessary in solving the problem. With rare exceptions, pathologists give no description of the inflammatory and other changes in the capsule and even orthopaedic surgeons usually mention it in the most vague way. Unfortunately there has not been sufficient time available as yet to carry out this study. The subject is presented now, therefore, chiefly for its suggestive interest.

In taking up this study it is of importance first to understand just what is meant by the term capsule. In a purely anatomical sense the capsule includes merely the synovial membrane and the capsular ligament with its accessory ligaments. The capsular ligament, "in its simplest form, consists of only enough fibrous tissue to support the synovial membrane"[1] and the necessary reenforcement is obtained by additional bands, the accessory ligaments, which are often of great strength. Of these the Y-ligament and the ligament of Winslow are the best known. At the wrist the V-shaped arrangement[2] of the two chief reenforcing bands, one being attached proximally to the radius and the other to the ulna, also requires mention as it is likely to afford considerable resistance when the bands are shortened. From a surgical standpoint, however, the pericapsular connective tissue and the various attached structures must be considered as integral parts of the capsule, since they not only increase its thickness and strength but are a common seat of the inflammatory changes which lead to contracture. The anatomical capsule receives important reenforcement from a number of structures[3]. In some joints it receives fibres from tendons attached just beyond the articulation, as is the case

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†Read before the American Orthopaedic Association at Atlanta, April 28, 1926.

in the semimembranosus at the knee, or from fascial expansions, as occurs over the posterior surface of the metacarpophalangeal joints. In many joints tendon sheaths are attached directly to the capsule or bursae are in intimate contact with it. In one joint muscular tissue (brachialis anticus) is closely adherent to it, while in certain others, muscles take their origin from it. Finally, in a few instances the capsule is reenforced by sesamoid bones or by cartilaginous plates, as in the case of the glenoid cartilages on the palmar surface of the metacarpophalangeal joints.

When this so called surgical capsule is studied in the joints of the extremities, two facts are at once evident. The capsule is much thicker and stronger on the flexor than on the extensor surface of the joints. Further, when cartilages are present, as the glenoid ligament at the shoulder, the cotyloid at the hip, the semilunars at the knee, and the glenoid cartilages at the metacarpophalangeal joints, they are attached to the concave segment of the joint.

While it is obvious that in all contractures which have persisted long enough for structural adaptation to take place every tissue on the contracted side of the joint is shortened, the part which the capsule plays in the maintenance of the deformity varies with the etiology. As far as the capsule is concerned, four main types call for discussion,—the simple postural, the traumatic, the inflammatory and the trophic.

The term "simple postural" is here used to designate the secondary change in the capsule brought about through structural adaptation alone. In this type growth is naturally an important factor, and when the contracture is of congenital origin or when it occurs during the growing period and is allowed to persist for a long time, it becomes particularly resistant and may furnish a definite obstacle to the correction of the deformity. This resistance may be assumed to be proportional to the strength of the accessory ligaments and the periarticular structures on the contracted side. In a paralytic knee contracture of this type of twenty years standing, the specimen of which was obtained for me by Dr. P. B. Steele, the posterior capsule measured fully a quarter of an inch in thickness. The effect of a contracted capsule of the simple postural type is well seen in old flexion contractures of the knee, in which, when the knee is straightened, either forcibly under anaesthesia or even gradually by the method of Wolff, subluxation of the tibia may result through the pull of the strong posterior capsule; and this may occur even when the hamstrings have been cut or lengthened. In the simple postural type also should be included contractures resulting from too long fixation of a joint in one position, although here other etiological factors, such as infection, may be present.

The traumatic type is more commonly met in joint fractures in which there has been extensive injury to the capsule and the pericapsular tissues with overlong fixation, particularly when the proper apposition of the fragments calls for the fully flexed or fully extended position. "The most obstinate cases are found in connection with fractures near the joint where adhesions have formed about the fracture."[4] The severity of the capsular

contraction in this type depends in all probability on the number and character of the attached structures and the extent of the hemorrhage.

In the inflammatory type the part played by the capsule in the contracture apparently depends on whether the inflammation is intra-articular or periarticular, and whether effusion into the joint cavity is marked. The fibrous capsular ligament itself is not readily infected and yields slowly to inflammatory destruction[5]. When the inflammation is intra-articular, if effusion is extensive, the capsule is distended and so probably plays little part in the resulting contracture. On the other hand, if the inflammation is a slowly progressive one without any particular amount of effusion, such as is commonly seen in the proliferative type of chronic arthritis, the capsular contraction may be pronounced. With periarticular inflammations, the capsular changes may be especially pronounced, particularly in joints in which tendon sheaths are intimately adherent to the capsule. "In septic compound fractures near the joints, muscles and ligaments undergo secondary changes with great rapidity and if adhesions occur, very obstinate immobility may result."[4] The only detailed description of the inflammatory changes in the capsule thus far found is that given by Nichols and Richardson[6] in their monograph on Arthritis Deformans. They describe the changes as follows:

"In all the cases of proliferative arthritis (rheumatoid type) changes occur in the capsule, usually synchronous with the changes in the synovial membrane. The change consists in a proliferation of the connective tissue of the capsule and leads to greater or less thickening, usually of the entire capsule. At the periphery of the joint this proliferation is continuous with the proliferation of the synovial membrane and cannot be distinguished from it. In the early stages this proliferation may result in the production of epitheloid cells with only a slight amount of intercellular fibrillar material, and there may be a marked infiltration of lymphoid and plasma cells, and numerous blood vessels. In later stages this tissue is converted into dense fibrous tissue, with sometimes numerous blood vessels about, which is a marked infiltration with lymphoid cells. In still later stages the blood vessels may show marked obliterative endarteritis, while finally the tissue appears only as extremely dense fibrous tissue with very few connective tissue nuclei and almost no blood vessels.

"The capsule (in the degenerative or osteo-arthritic type of joint) shows as a rule much less marked changes than are seen in the articular ends of the bones and also less than is seen in the proliferative type. As a whole the capsule is not much thickened, although the fibrous tissue of which it is composed may be exceedingly dense. As a rule it shows no evidence of infiltration of lymphoid cells, although in certain areas masses of lymphoid cells may appear. In most cases the capsule at the point of attachment to the margin of the joint shows, as has just been described, transformation into fibrocartilage or cartilage. In some, however, more commonly in the larger joints, and most marked in joints associated with disease of the central nervous system, the changes in the capsule are

extreme. In some instances the capsule may be enormously thickened from formation of dense fibrous tissue, and in some of these the capsule is very vascular with marked obliterative endarteritis. Moreover, marked metaplasia of the connective tissue of the capsule may result in the formation of cartilaginous or bony masses in the capsule itself."

The trophic type, seen in nerve lesions and after ligation of the main artery of the extremity[7], is attributed to general fibrotic changes. T. E. Hammond[8] has discussed most interestingly the reasons for the development of these changes after certain nerve injury and not after others. He ascribes it to chronic reflex vasomotor changes brought about through the irritation of the uninjured afferent fibres by stretching of the ligaments. These trophic contractures are notoriously resistant, particularly in the hand.

In reviewing the various pathological changes in the capsule, it is evident that, while in all cases of joint contracture the capsule undergoes structural adaptation after a time and thus plays its part in the perpetuation of the deformity, the cases in which it offers the chief or the most important obstacle to correction are those of the inflammatory type in which the capsule is surrounded by considerable connective tissue or has important structures intimately attached to it. When the latter are the seat of inflammation, the resistant fibrous capsule acts as a bridge or framework for the granulation tissue.

That the capsule is chiefly responsible for the contracture is indicated when the muscles or the tendons on the contracted side are not unduly tight, as determined by palpation. In the finger joints Dickson[8] has described "a simple method to differentiate between tendon shortening, ankylosis and stiffness of the joint: pressure is applied on the head of the first phalanx until the metacarpophalangeal joint is flexed as far as possible; if flexion of the interphalangeal joint is then possible the limitation of movement is due to a condition in the capsule; if, however, this joint cannot be flexed in this position, the condition is one of tendon fixation or shortening"[4]. The same principle can apparently be applied to the knee, extension being tested with the hip fully hyperextended and then slightly flexed.

Until the recent war the capsule had received little special attention. Its contraction was considered merely as a part of the general tissue change and was subjected to the same corrective procedures,—namely, forcible manipulation under anaesthesia or gradual stretching by the method of Wolff. The indications and limitations of these procedures are so well known that they require no further discussion. During the war attention was necessarily directed to the relief of joint contractures and the value of elastic traction in contractures of the fingers due chiefly to capsular changes was demonstrated in the Bangor Military Hospital, particularly by Abbott, Baldwin and Danforth[4].

Operative relief of the contracted capsule seems to have been but rarely employed. Lange, in his discussion of joint contractures in

Joachimsthal's Handbuch der Orthopaedische Chirurgie, published in 1905–1907, states that "Bardenhauer once divided the posterior capsule of the knee in a severe contracture; with this exception in recent times the operative lengthening of the shortened capsule has not been carried out". Murphy[5], in his Contribution to the Surgery of Bones, Joints and Tendons, discusses the pathological changes in the capsule, mentions its division in the correction of deformity, and says that "the division of the joint capsule, associated with the elongation of tendons, does not receive sufficient attention in the literature on the subject; it is necessary to secure a permanent and a good result". Jones[4] mentions shortening of the capsule of the elbow joint, either anteriorly or posteriorly, which is sometimes so thickened and firm that no amount of force under anaesthesia will stretch it, and quotes Wheeler as having suggested in a limited number of instances its division through lateral incisions. Soutter[9] and others speak of the necessity of dividing the capsule in deformities of the toes. The most general consideration of the subject is found in the recent work of Steindler[10], who discusses the indications for capsulotomy at the wrist, hip, knee, fingers and toes. The only reports of series of cases found thus far are those of Heyman and Putti. Heyman[11] reports a number of cases of contracture of the metacarpophalangeal joints treated by open division of the capsule through an inch-long incision made over the dorsal surface. Putti[12] discusses the contracture of the posterior capsule of the knee and reports its division in eight cases through a median posterior incision.

All of these, it will be noted, speak only of simple open division of the capsule, except that in the toes the subcutaneous method is advised. The only instance of possible subperiosteal separation of the capsule thus far found is that which forms the basis of Ober's[13] operation for the relief of club-foot.

Subperiosteal separation of the contracted portion of the capsule possesses certain definite advantages. As compared with forcible correction it affords a means of overcoming contractures not amenable to force, of avoiding the danger of fracture as well as of troublesome reaction from traumatism, and of causing less pain. Over simple capsulotomy it offers the advantage of preserving the continuity of the capsule with the consequent shorter period of fixation and the lesser danger of recontracture. It also has the very decided advantage that in most joints it can be performed subcutaneously, thus making of it a decidedly simple procedure.

The subperiosteal separation of the capsule should be performed usually on the side of the convex, or condylar, segment of the joint on account of the attachment of cartilages to the concave segment of some joints. The wrist furnishes an apparent exception to this rule. When carried out subcutaneously, an osteotome makes a suitable elevator for the larger joints, while for the smaller ones and even for the larger joints in children, a satisfactory one can be made from a tenotome by cutting the blade off squarely across near the middle and sharpening the end and both sides. The skin is first incised with an ordinary tenotome, well on the side

of the joint and close to the joint line, the blade is carried down to the bone and then the capsule alone is split longitudinally from the joint line to its insertion. The elevator is now introduced and the attachment of the capsule is separated, a sufficient amount of the periosteum being taken with the capsule to permit of its ready re-adhesion after the contracture is corrected. It seems simpler to pass the elevator through the slit in the capsule into the joint cavity and to work from the joint cavity outward. After the separation of the capsule has been carried beyond the mid-point from one side, the process is repeated on the opposite side. If the subcutaneous method seems insufficient or unsafe, a formal incision on one side only will usually be sufficient; should it not be possible to carry the separation far enough toward the opposite side, this may be completed on that side subcutaneously.

It must not be expected that the contracture can be fully corrected in all cases after the capsule has been freed. This will depend on how much the other tissues are implicated. When the capsule is the chief factor, however, the moderate resistance in the other tissues can be expected to yield to the gradual method of correction before the periosteum has a chance to re-adhere. This was observed in a very resistant flexion contracture of the proximal phalangeal joint of the little finger, following a Colles' fracture in which the tendon sheath evidently played a considerable part in the contracture and the joint could not be fully straightened after the capsule was separated but yielded gradually within the first week. It was also observed in a paralytic flexion contracture of the knee, operated on through a lateral incision by Dr. C. C. Yount, in which two attempts at correction by ordinary means had failed. A partial relapse had taken place since the last attempt and when the capsule was freed, it separated fully an inch but the knee still did not come entirely straight. However, it soon yielded to the gradual method which before had been unsuccessful.

Thus far subperiosteal separation of the capsule has been used by the subcutaneous method for the relief of contractures of the fingers, metacarpophalangeal joints, the wrist, the elbow, and the ankle, and by the open method of the knee. The wrist and the elbow contractures were of congenital origin and had resisted long continued and efficiently carried out measures for gradual correction. In the case of the knee it has already been noted that two unsuccessful attempts at gradual correction had been made. This method has also been employed by Dr. Yount as a modification of Bennett's operation for lengthening of the quadriceps and he has kindly furnished me with the following note of the case:

"The contracture was one following compound fracture of the femur. Plastic preparation of the parts of the patellar tendon was done according to the method of Bennett, but after having incised the scar area in this manner, it was still impossible to flex the knee. It was evident that the limitation of flexion was caused by the extension of scar tissue to the lateral capsule of the knee joint. In order to free this part of the obstruction a method suggested by Dr. Silver was done as follows: The capsule and scar tissue in it and over it was incised beginning 4 cm. above the upper border of the

patella and extending laterally on each side. This incision was carried to the bone. Then by subperiosteal stripping the tissue was freed down to the joint crevice. After this was done it was possible to flex the knee to about 80 degrees. The advantage in this at the time seemed to be, that instead of having a wide gap at the joint crevice, as would have been the case had the capsule been incised at the joint line, the two flaps of thickened capsular and fibrous tissue glided down nearly to the joint line but did not pass it, so that the joint crevice was not exposed. After three months, the patient was able to extend the knee to 175 degrees against gravity and to flex it to 120 degrees, while the gait was nearly normal. This is by far the most satisfactory result that I have seen in my experience in the operation of Bennett for a plastic lengthening. I attribute this largely to the manner in which the capsule was treated in this case."

As far as the applicability of subperiosteal separation is concerned, the shoulder seems to offer little occasion for its use, with the possible exception of resistant cases of subluxation following obstetrical paralysis. At the elbow subcutaneous separation offers no especial difficulties either anteriorly or posteriorly, the ulnar nerve being the only structure that requires guarding. Hence, there is little cause for hesitation in testing the effect of separation in doubtful cases. At the wrist, while the entire capsule is involved in a flexion contracture, the main resistance is probably furnished by the strong V-shaped arrangement of the two main accessory ligaments. These can be readily freed subcutaneously at their origin from the radius and the ulna, leaving the remainder of the contracture to be cared for by the gradual method. This is apparently the only joint in which it is best not to follow the rule of separating the capsule on the side of the convex segment. The hip certainly presents occasional cases, particularly of the traumatic type, in which subperiosteal separation apparently promises to be of considerable benefit. There seems to be no reason why this cannot be carried out subcutaneously with efficiency and safety. The knee is the one joint where the open separation is probably necessary, although it may be possible to work out a satisfactory subcutaneous technique. Here the approach is best made through an external incision just in front of the biceps tendon. The tissues should be stripped from the insertion of the capsule, so as to protect the popliteal artery. Some bleeding may be encountered from one of the posterior articular branches unless the separation is kept high. Especial care should be taken to free that portion of the capsule attached just above the intercondyloid notch, as this seems to afford the chief resistance to correction. The method appears particularly suited to the relief of finger contractures. The special elevator simplifies the separation and enables it to be readily performed subcutaneously under local anaesthesia without injury to the tendons, blood vessels, or nerves. It is believed that this procedure will prove especially serviceable for the improvement of function in hands crippled by the various affections classed under arthritis deformans. At the ankle, cases of resistant equinus in old club-feet in which the tendo Achillis has been previously divided are not uncommonly met where the equinus is due more to capsular shortening than to recontracture of the calf muscles and these can be best treated by subperiosteal separation carried out distally to the joint. In

the toes the method can also be used in place of simple division of the capsule, although here there is in most instances less necessity for such special care.

## REFERENCES


1. Piersol, George A.: Human Anatomy. Philadelphia, J. B. Lippincott Co., I, 108, 1907.
2. Spalteholz: Hand Atlas of Human Anatomy. Philadelphia, J. B. Lippincott, I, 205, 1923.
3. Quain: Elements of Anatomy. London, Longman, Green & Co., Vol. II, Pt. II, 1894.
4. Jones, R., and Lovett, R. W.: Orthopaedic Surgery, New York, Wm. Wood & Co., 75–109, 1923.
5. Murphy, J. B.: J. Am. Med. Assn. LVIII, 1912.
6. Nichols, E. H., and Richardson, F. L.: Arthritis Deformans. J. Med. Research. XXI, 171–172, 188–190, Sept. 1909.
7. Jones, R.: Orthopaedic Surgery of Injuries. I, 262, 1921.
8. Hammond, T. E.: J. Orthop. Surg. (New Series) I, 320, June 1919.
9. Soutter, R.: Technique of Operations on the Bones, Joints, Muscles and Tendons. New York, Macmillan Co., 1917.
10. Steindler, A.: Operative Orthopaedics. New York, Appleton, 1925.
11. Heyman, C. H.: Surg. Gynec. Obst. XXXIX, 506–507, Oct. 1924.
12. Putti, V.: Chir. d. org. di movimento. V. Fasc. 1. Feb. 1921.
13. Ober, F. R.: J. Am. Med. Assn. LXV, 621, Aug. 14, 1915.


## DISCUSSION

Dr. J. W. Sever, Boston, Mass.: I am very glad of the opportunity to discuss this paper of Dr. Silver's. It is always interesting to me the ease with which he does the things which seem difficult. The question that he particularly speaks of is that of doing these periosteal tenotomies or capsulotomies on the convex side of the joint. It does not seem as if that would relieve flexure deformities. Also in speaking of the Ober operation, which is a release of the deltoid ligament on the inner side of the foot, I think that is a particularly good operation and could be done with a tenotome as it used to be done years ago by Dr. Brackett and Dr. Lovett. Cutting the posterior capsule, which is often contracted, can also be done easily with a tenotome. In the case of the posterior capsule of the knee joint I should think it would be extraordinarily difficult to cut it with a tenotome because we are in the presence of structures we cannot see and I personally think it would be a very dangerous operation.

The question that came to my mind as I read his paper, particularly regarding periosteal elevations of the capsule, is what happens later, after you have lifted the capsule periosteally. Do you have a subsequent periosteal overgrowth that is going to limit your motion? I think in the posterior capsulectomy for knee deformities undoubtedly the deformity was produced from an inflammatory condition or a destruction of the posterior capsule.

Another question is, what effect does the rapid correction, particularly in the hip and more particularly in the knee, have on the circulation. Perhaps some of you have had the unfortunate experience of correcting a deformity to normal and then having to amputate the leg. That happened to me. I apparently had corrected the knee flexion easily under anaesthetic, but later interference with the circulation came on, followed by amputation, due to too forcible or too active stretching of the popliteal vessels. I think Dr. Silver's method would be ideal with the fingers or with joints that you can correct readily, but with the knee or hip I think it would be a dangerous procedure. I think this is a very suggestive paper and a very didactic and skilled presentation which

does not leave very much for any one to add to it. These are just a few points that came to me while I read it.

Dr. G. E. Bennett, Baltimore, Md.: Personally, I have been very much interested in the paper which Dr. Silver presented because I think it presents a very fine line of thought. I am particularly interested because of the fact that for the last few years Dr. Baer has been emphasizing to the men who have been working with him the importance of subperiosteal elevation of ligaments for contractures resulting from fractures. I have used it in the elbow following traumatic injuries. The operation on the elbow joint has been done by open incision with a subperiosteal loosening up of the ligaments. The same is true of the knee joint. I do not recall whether Dr. Baer has done it in inflammatory cases or not. We have subperiosteally elevated the posterior capsule with a fair correction of the deformity. I wish to thank Dr. Silver for referring to my work. I think the procedure which he mentioned is a very good one, that is, subperiosteally loosening the capsule. However, I have a number of very severe cases of scars in which we had lengthened the quadriceps and in which we had comparatively no capsular contraction. In the average case I do not feel that this is necessary. The great objection is that you are bringing more or less trauma in a field where you have already done a mutilating operation. I think the most important line of thought is the question of old atrophic conditions. If a subperiosteal elevation of the capsule can be accomplished without any bad results, it would certainly lessen the number of fractures that result by manipulating arthritic joints. This, to me, is a very outstanding part of the paper. I also think the fundamental basis brought out in the paper in the classifying of the anatomical and surgical capsule is very pertinent. I want to congratulate Dr. Silver. No one, except probably Sir Robert Jones, has given the capsule so much consideration.

Dr. Robert Schrock, Omaha, Nebraska: The principle of separating structures *en bloc*, those structures being the capsule, tendon and supporting ligaments, is the thing that will not produce trauma from the fact that you do not destroy the relation of those structures to each other but the relation of those structures to their base. We all know that a rent of ten to fifteen degrees in knees that have been previously contracted and have been straightened out by the means that we have, either by continuous traction, continuous leverage, or by the various described appliances, is not quite accomplished and the structures under the popliteal space feel as though they should give a little more. Our palpation does not go quite deep enough. It is the posterior capsule that is the offending membrane. From the standpoint of the posterior capsule, when those knees are subjected to rather radical surgery the distance those structures have to go in the straightening is rather surprising. An inch or an inch and a half is not quite enough. Can those structures be split far enough from one attachment, or is it necessary to cut the attachment from the tibial surface as well in order to gain that space? Following that is the question Dr. Sever has brought out, as to whether the new tissue that is laid down or may be laid down with the capsule will not form a bony block or will they undergo physiological absorption and not leave a small track of osseous tissue or bone? We know that elastic traction is the most efficient traction we have for overcoming deformity, because this capsule has lost its elastic fibrous tissue. We supply that elastic element with the elastic element in our external devices. This means will bring back to the scar tissue that elastic quality which it has lost either from inflammatory reaction of fibrous exudate or from loss of function from simple postural deformity.

I would like to ask a question, whether adequate distance can be secured in slitting the distal end of the femur.

Is the separation from the femur adequate to give the necessary distance and, if not, is it possible to make the separation an additional distance from the tibia?

Dr. Leo Mayer, New York, N. Y.: I wish Dr. Silver would explain one point to me. I did not understand what he meant by making a slit in the capsule and working from the capsule out. I do not see how this resembles the stripping procedure back of the ankle. It seems to me that the ligaments are so complicated that it would be impossible

to do this method. I wonder if there would not be less trauma by using a tenotome in the joint space, cutting the capsule straight across.

Dr. A. H. Freiberg, Cincinnati, Ohio: Ever since the original communication from Dr. Silver came to me I have used this method with a great deal of satisfaction. Like all true original things, it is very simple.

The question of rapid correction of the deformity having been referred to, I might say that I think there is less danger of injury from rapid correction by this method than by the older method. I think that much of the danger in rapid correction of the knee deformity is from the pressure of blood which is poured out around the muscles and nerves, so that this interferes with nutrition in these parts after the correction is accomplished.

I think in Dr. Silver's method we have a distinct addition to our resources.

Dr. David Silver, Pittsburgh, Pa. (closing discussion): Replying to Dr. Sever, it was not my intention to discuss the general problem of contractures and the dangers in their correction, but merely the part played in them by the capsule. Our experience has shown that in some contractures it is not possible to secure complete correction by the usual methods and that in these cases the capsule seems to be responsible for this residual amount, as is shown by full correction being possible after subperiosteal separation of the capsule. As far as too rapid correction of severe contractures is concerned, its dangers are, of course, well known. With reference to subcutaneous separation, I want to emphasize the fact that I did not recommend this at the knee but stated that the open method should be used.

In answer to Dr. Schrock, I believe that separation of one end of the capsule is entirely sufficient, provided the separation be carried to the mid-point on each side. As regards possible subsequent trouble from new bone formation, this has thus far not been encountered; moreover, we have had several cases of extension contractures of the metacarpophalangeal joints where bone prolification could have been readily detected if it had occurred.

# TRAUMATIC ASPHYXIA

## Report of Four Cases

BY H. EARLE CONWELL, M.D., F.A.C.S.

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A review of the surgical literature on the subject of traumatic asphyxia would lead one to believe that it is a rare condition. In spite of this, however, it is our belief that the condition is a fairly frequent one and that the scarcity of literature on the subject may be explained by the fact that a certain proportion of cases are not diagnosed and that numbers of the diagnosed cases are not reported.

It is probable that, because of the increased use of motor driven vehicles and increased speed of locomotion, traumatic asphyxia will be more frequently encountered, and for this reason a brief review of the condition seems justified.

It is an established fact that the condition is always caused by a sudden and violent compression of the chest or abdomen, or both. Apparently this pressure may be either prolonged or of very short duration. The condition is characterized by a marked discoloration immediately following the injury, which usually involves the neck, head and face down to the clavicle in front and posteriorly along the back and shoulders at the level of the lower border of the trapezius muscle. Sometimes, however, the discoloration extends further down the chest and back and down the arm to the attachment of the deltoid muscle (Case 1, Figs. 1 and 2). This discoloration is either a livid violet, or reddish purple, or almost a black color, according to the severity of the injury. Apparently the more severe the injury, the darker the discoloration encountered. The discoloration is not always uniform, but in certain instances may give a mottled appearance, certain areas being darker than others. In only one of these cases was the discoloration entirely confluent. In all four cases of this series the discoloration was accompanied by bilateral subconjunctival hemorrhage. In each of the four cases in this series there was a moderately well marked line of demarcation between the involved area and the normal tissue. In one case there was a complete circle of the neck of apparently normal colored skin, which the patient stated was the area covered by a tightly buttoned collar at the time of the accident (Case 1, Figs. 1 and 2).

Death apparently never results from the asphyxia, but in the fatal cases is due to associated injuries. In cases that recover the lividity usually lasts only a few hours, although the deep colored spots may not clear up for several days, or even weeks. Subconjunctival hemorrhages clear up very slowly, and because of the fact that optic nerve atrophy has been reported, a guarded prognosis as to sight should be given.

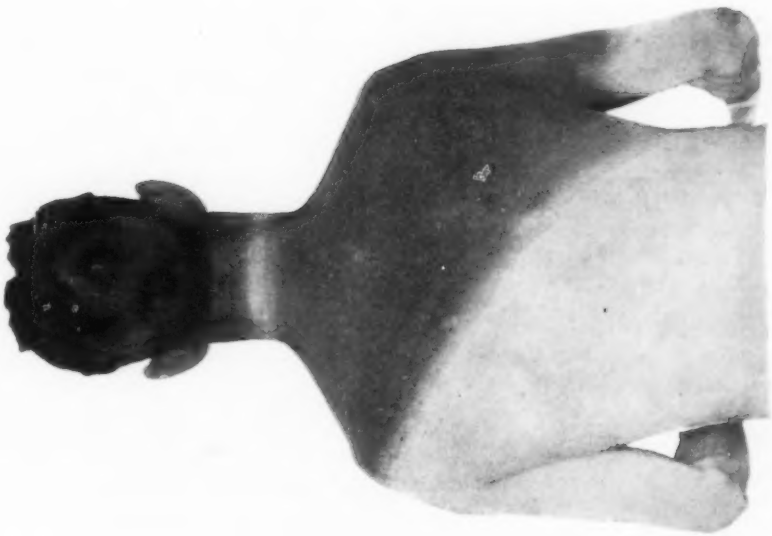


FIG. 2. CASE 1

FIG. 1. CASE 1

Apparently unconsciousness of short duration occurs even in those cases which recover promptly.

DaCosta states that the asphyxia is due to compression of the abdominal veins, causing distention of the superior vena cava and its tributary veins and capillaries, with resulting capillary paresis, with or without capillary rupture, and that the marked involvement of the head, neck and face, as well as the upper thorax, is probably due to the incompetent valves of the innominate and jugular veins.

In the more marked cases where the discoloration extends low on the arms and chest, accompanying involvement of the head, neck and face, it is probable that incompetent valves of the subclavian and axillary veins are responsible.

It is rather difficult to explain certain cases in which one side of the head, neck or face is involved more than the other side (Case 3), as well as those cases in which one side of the chest or one arm may be involved (Case 1, Figs. 1 and 2), but the difference in the length of the right and left innominate veins and the fact that in certain cases the pressure may be unilateral is offered as a probable explanation.

Quoting from the very able article by Green in Surgery, Gynecology and Obstetrics, August, 1922:

"We must remember that in this type of asphyxiation we are not only dealing with the withholding of air from the lungs, but that the venous blood in the large veins of the thorax, neck and head has been forced backward into the capillaries of the skin by the compression of the chest and abdomen, thus producing an intense discoloration of the skin. Perthes explains the sharp limitation of this discoloration by lack of competent valves in the veins of the head. (There are no valves in the innominate and internal jugular veins, except a pair where the jugular enters the innominate. These are irregular and incompetent. There are two pairs in the external jugular, one at its junction with subclavian and the other just above the clavicle. Both sets of valves are incompetent.) Hueter in explaining this discoloration thought that it was due either: (1) to the extreme distention and rupture of the vessels of the skin of the face and neck from the sudden upward pressure; or (2) that the pressure on the abdominal and thoracic sympathetic nerves produces vasomotor paralysis, which results in the distention of the vessels with blood. Perthes accepts Hueter's first explanation, but believes that the capillaries are actually ruptured and allow the blood to be extravasated into surrounding tissues. Burrell and Crandon believe the condition to be due to vasomotor paralysis, accepting the second explanation of Hueter. It remains for Beach and Cobb to show conclusively in their exhaustive treatise that it was not an extravasation of the blood outside of the vessels, but that the intense pressure from the blow had forced the venous blood upward against the incompetent valves and backward into the capillaries of the face and neck. This they proved beyond question by removing sections of skin for microscopic study. The discoloration is inclined to blanch a little in pressure

and clear up rapidly without going through the various stages of discoloration as shown where blood is extravasated into the tissues."

Artificial respiration and the use of oxygen and stimulants have been advised for treatment. None of these were necessary in this series of cases. Routine treatment for shock should be given. Apparently the asphyxia itself is not dangerous, provided associated conditions can be handled.

In such cases as recover the use of colored glasses is advised and a nutritive diet.

## CASE REPORTS

CASE 1. J. D. H. (Figs. 1 and 2)—white, male, age 22. Admitted to Bessemer General Hospital May 21, 1925, about 6.30 P.M. Seen in consultation with Dr. R. W. Waldrop.

Patient stated that he was driving a truck; that the truck was struck by a fast moving railroad train, resulting in overturning of the truck and pinning patient beneath. Patient stated that he had suffered compression of chest, abdomen and pelvis and that he was unconscious for several minutes. Physical examination revealed a marked discoloration, reddish purple in color, covering the face, neck and shoulder, extending downward to nipple line, anteriorly, and to the spine of the scapulae, posteriorly, and covering the entire circumference of the right arm, upper half. There was a definite collar of normal tissue at the base of the neck where the collar of the shirt had been buttoned. There was severe bilateral subconjunctival hemorrhage, with definite impairment of vision. Pulse 90, temperature normal. Patient complained of severe pain in the right pelvis. Patient was absolutely conscious and gave a very complete history of his injury and symptoms. Radiograph showed fracture of the superior ramus of the pelvis and of the pubis, right side. There were no other fractures. Patient was treated routinely for shock and gradually improved. Patient was later transferred to Employees' Hospital, Fairfield, Alabama. The discoloration gradually disappeared over a period of nearly two weeks. Patient was discharged from hospital July 2, 1925, after routine treatment for fracture of pelvis. All symptoms of traumatic asphyxia had disappeared within two weeks following injury. Had excellent results from other complications.

CASE 2. R. G.—white, male, age 16. Admitted to Employees' Hospital, Fairfield, Alabama, February 18, 1926, at 10.40 A.M. Seen in consultation with Dr. Lloyd Noland. Injury occurred some twelve hours previous to admission, by overturning of truck and crushing of patient beneath truck. According to statement of eye-witnesses, there had been marked compression of the abdomen and chest. Patient was still unconscious when admitted to hospital, having remained unconscious since injury. Physical examination revealed a very dark discoloration involving the entire head, face and neck and extending to the clavicles, anteriorly, and to the spine of the scapulae, posteriorly. There was marked bilateral subconjunctival hemorrhage. Temperature 104°. Pulse 110. Radiographic examination revealed extensive fracture of vault and base of skull. Patient gradually became worse and died on February 19, 1926, at 4.00 A.M., sixteen hours following admission. Autopsy was not allowed.

CASE 3. V. R.—white, male, age 22. Admitted to Employees' Hospital, Fairfield, Alabama, February 8, 1926, at 6.30 A.M., with history of injury received only forty-five minutes before admission. Patient stated that he had been caught between a crane and the wall of a building, crushing his chest and abdomen. Patient stated that he was unconscious for a few minutes following injury but was perfectly conscious on admission to hospital. Physical examination revealed a severe contusion of chest, abdomen and pelvis, with multiple fractures of ribs on right side. There was a dark violet discoloration of the head, neck and face, extending down to the clavicles, anteriorly, and along the

upper border of the scapulae, posteriorly. There was marked abdominal and thoracic tenderness and rigidity. The patient was severely shocked. Pulse 150. Temperature subnormal. Marked subconjunctival hemorrhage, bilateral. Patient failed to respond to stimulants, gradually became worse and died at 3.30 P.M., February 8, 1926, some eight and one-half hours following injury. Autopsy was not allowed, but death was unquestionably due to severe thoracic and abdominal injuries.

CASE 4. H. G.—negress, mulatto, age 22. Admitted to Employees' Hospital, Fairfield, Alabama, March 22, 1926, at 10.20 A.M., with history of injury in automobile accident two hours previous, by having automobile crush her abdomen and chest. Patient stated that she was unconscious for several minutes following injury but was conscious on admission. Physical examination showed very marked reddish discoloration over entire left half of face, extending downward to base of neck. There were several dark spots on right side of face, but not marked. Marked left subconjunctival hemorrhage, with slight right subconjunctival hemorrhage. There was only moderate shock. There was severe contusion of the right elbow, with moderate tenderness over left chest and over the left supraclavicular region. Radiographic examination revealed a chip fracture of the right ulna, upper third. Patient gradually improved and was discharged on March 26, 1926. Was seen frequently following discharge until April 2, 1926, at which time all discoloration had disappeared except for a persistent subconjunctival hemorrhage, left. On April 10, 1926, this had practically disappeared and patient had fully recovered.

## CONCLUSION

1. Traumatic asphyxia is probably much more common than surgical literature would show.

2. Traumatic asphyxia should always be kept in mind as a possible complication of injuries of chest and abdomen.

3. Temporary unconsciousness usually accompanies the condition. Convulsions are seldom present. Subconjunctival hemorrhage is an invariable accompaniment.

4. The discoloration encountered may be either violet, reddish purple or black. Discoloration usually clears up within a few days.

5. Death is probably never due directly to the traumatic asphyxia, but in fatal cases is due to associated injuries.

## REFERENCES

1. DACOSTA: Modern Surgery, Ed. 8, Philadelphia, W. B. Saunders Co., p. 1014, 1919.
2. THOS. M. GREEN: Surg. Gynec. Obst., XXXV, 129, August 1922.
3. TARDIEU, ABRROISE: Etude medico-legale sur la pendaison la strangulation et la suffociation. 1870.
4. HUETER: Deutsche Ztschr. f. Chir., IV, 330, 1873–74.
5. PERTHES, G.: Deutsche Ztschr. f. Chir., L, 436, 1898–99.
6. BEACH, H. H. A. AND COBB, F.: Ann. Surg., XXXIX, 481, April 1904.
7. RUPPANNER, E.: Cor.-Bl. f. schweiz. Aerzte, XXXIX, 45, 1909.
8. RYERSON, E. S.: Canad. Pract. and Rev., XXXII, 195, 1907.
9. ETTINGER, W.: Wien. klin. Wchnschr., XX, 665, 1907.
10. LANGE, E.: Deutsche Ztschr. f. Chir., CXX, 76, 1912–13.

# PECULIAR BEHAVIOR OF GIANT-CELL TUMORS

BY C. C. CHATTERTON, M.D., AND A. E. FLAGSTAD, M.D.

According to most authorities, giant-cell tumors are benign growths and should be treated as such. This question is by no means closed; there are those who still hold that metastasis occasionally does occur.

Bloodgood in 1919 reported forty-seven cases in which none metastasized. Coley reported a series of fifty cases of which nine metastasized. The latter contends that there are borderline cases; these bear expert watchfulness. Occasionally, according to Coley, a frank giant-cell tumor undergoes malignant changes. He reviews the literature quite completely and cites other cases by Gross, Stewart, Oertel and others to illustrate that metastasis does occur. He quotes Norton and Duffy who say, "It is often hard to make a positive diagnosis and at times requires great skill".

Stone and Ewing hold that rarely, if ever, does a true giant-cell tumor metastasize. In reporting a case they conclude that the malignant change in this particular tumor was due to repeated operative trauma. After reviewing the literature they say, "There is no satisfactory record of metastasis of a giant-cell tumor in its original form". Metastasis in recorded cases, they feel, is due to repeated trauma. Stone and Ewing further state: "The joint cavities are occasionally invaded by undermining of the cartilage which allows collapse and rupture into the joint. This complication belongs to the most aggressive type of disease and is distinctly rare."

Codman states that over a hundred cases of giant-cell tumor have been registered without a true case of metastasis. The questionable cases are probably due to error in primary diagnosis. He feels that metastasis, myeloma and bone cysts are the only type of tumors that are likely to be confused with giant-cell tumor. Roentgen diagnosis will be simplified if one remembers two facts:

First: Whether the growth involves the condylar aspect of the femur and encroaches upon the joint cartilage.

Second: Whether growth is expansive, giving a picture of inflation, the shaft being distended rather than in the center of the growth. The transverse diameter as a rule is greater than the longitudinal.

It is with this difficulty of differential diagnosis and occasional peculiar behavior of giant-cell tumors in mind that we shall present these two cases.

Case 1 illustrates a giant-cell tumor, so diagnosed grossly and microscopically at biopsy. The history, extending over a period of eight years, the roentgen ray, and the physical examination suggested a giant-cell tumor. The tumor suddenly and apparently without provocation underwent malignant change followed shortly after amputation by pulmonary metastasis and death.

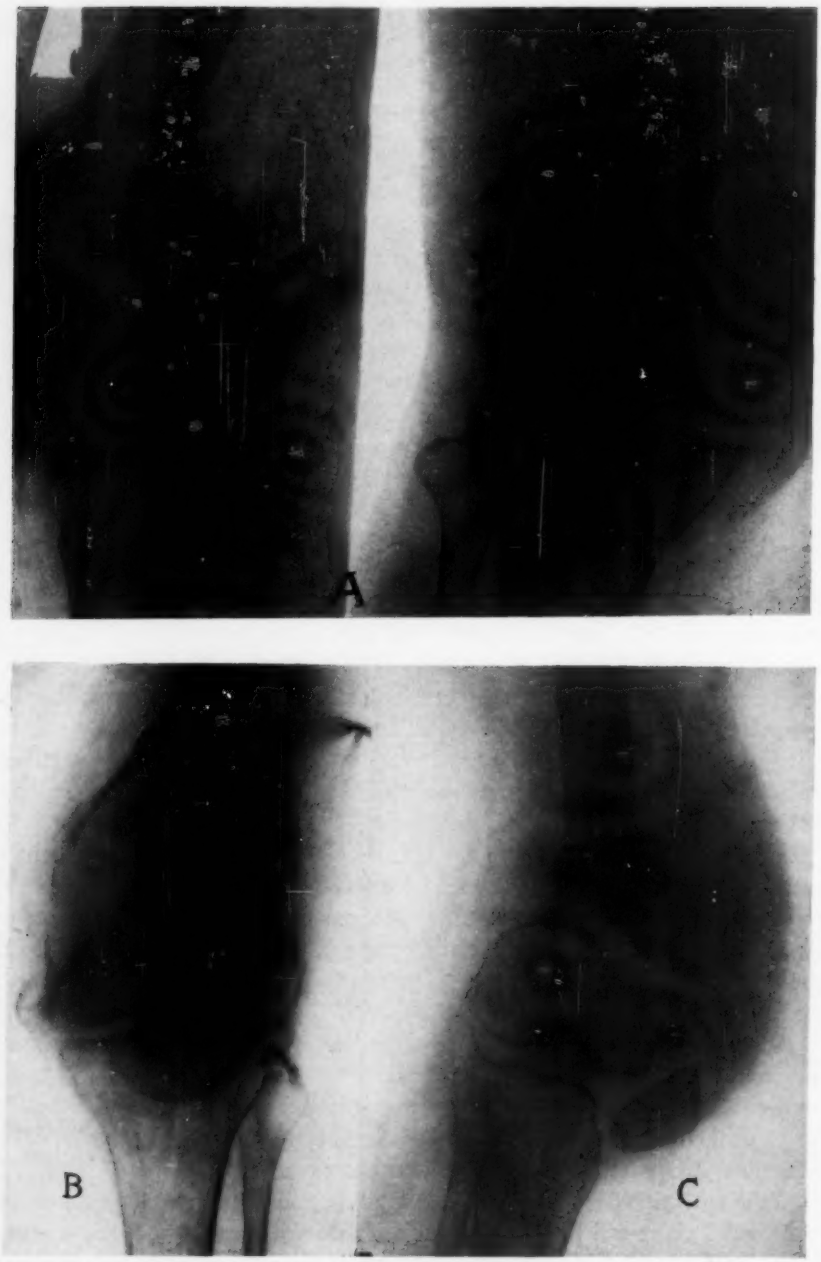



FIG. 1

Case 1. A. Roentgen ray December 4, 1920, before curettage. Central tumor, condylar aspect of femur, cortex intact. B. Roentgen ray February 22, 1923. Tumor shadow about the same. C. Roentgen ray October 10, 1923. Tumor shadow invading soft tissue, cortex broken, evidence of definite progression.

Case 2 illustrates the aggressive type of giant-cell tumor. This tumor is seen but rarely according to Stone and Ewing. It is the type of tumor that breaks into the joint cavity, resembling from a clinical and roentgen standpoint a malignant growth, but microscopically it is truly benign.

Case 1. Woman, age thirty years, was first seen on December 4, 1920. Her complaint at this time was a sore and painful left knee. She said that her illness began in 1915, although she felt that the left knee had never been just right. In 1915 she began having occasional pain in the knee, which gradually increased with swelling until, in 1918, she consulted a physician. At this time she was told that she had rheumatism and was treated accordingly. During the next several years she consulted several physicians. Gradually the discomfort increased, the knee became more swollen and she definitely favored it. In June 1920, she stumbled and sustained an injury to the knee; since then, the pain, swelling and disability have been much increased. She had used crutches since her injury. The patient had had the tonsils and appendix removed. At eighteen she gave birth to a child. Physical examination in 1920 was essentially negative except for moderate anaemia, a swollen and painful left knee. Motion at the knee joint was slightly limited, there was no fluctuation present. Blood Wasserman was negative, urine normal, blood showed a moderate secondary anaemia. Roentgen ray showed an old supracondylar fracture of the left femur. Just below the fracture the shaft was rarefied, the area of rarification involving the condylar aspect of the femur. The shadow was spherical and the cortex intact throughout. The picture suggested either a giant-cell tumor or a bone cyst. December 5, 1920, a portion of the tumor was removed. Grossly and microscopically a diagnosis of giant-cell tumor was made. Grossly the tumor resembled currant jelly in appearance and consistency. It bled moderately under curettage. The curetted cavity was cauterized with phenol and glycerin. Postoperative course was uneventful. During the next several years our patient was seen at frequent intervals. The first six months following the operation she wore a cast after which a leather support was worn. During this period the knee slowly but definitely improved; there was less pain; the swelling receded, and the general health improved. The latter part of September 1923, without provocation, terrific pain developed in the left knee. This differed from any previous pain. For three weeks she could not sleep, the swelling increased and the patient rapidly lost weight. October 11, 1923, the patient's features were drawn, there was evidence of suffering, loss of weight and loss of sleep. The knee showed marked muscle spasm, tenderness to touch, redness, local heat

Fig. 2

Case 1. Gross section. Osteogenic sarcoma. Entire condylar aspect of tumor replaced by tumor tissue. Cartilaginous pearls of tumor tissue extending up medullary cavity.

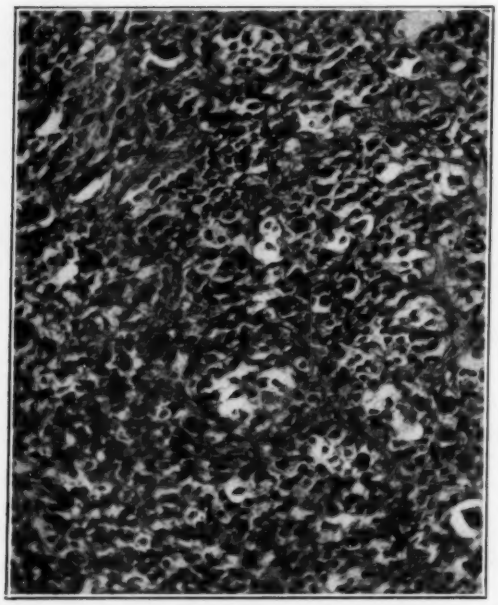
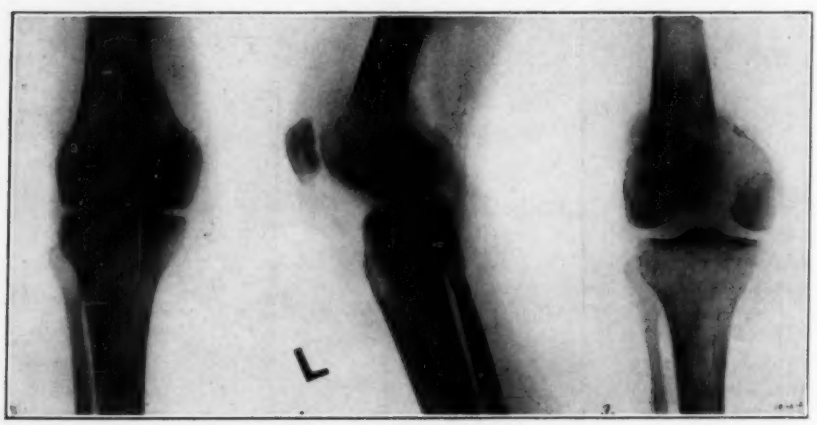


FIG. 3

Case 1. Microscopic examination after amputation. Very cellular stroma with extensive mitosis present.

and dilatation of the superficial veins. The circumference was two inches greater than on the last measurement in July 1923. Chest examination was negative, there was no cough or dyspnea. Because of difference in type of pain, definite evidence of progression with marked constitutional symptoms, the patient was advised amputation and told to consult another physician before this was done. October 15, a mid-thigh amputation was made. The tumor after amputation showed bloody serum and fine gelatinous debris; the cortex of bone was broken through. Dr. E. T. Bell of the University of Minnesota reported, "Very rapidly growing osteogenic sarcoma". Three weeks after amputation the patient began to complain of night sweats, cough and slight dyspnea. Examination at this time showed slight dullness, loss of breath sounds over the left lower lobe, definite tachycardia and slight displacement of the heart to the right. There was a rapid increase of subjective and objective chest symptoms. Roentgen ray, on November 23, showed extensive effusion over the left lung. The heart was displaced into the right axilla. November 24 and 27, thoracentesis and large quantity of bloody fluid removed. Death occurred December 4, probably from sarcoma of the




A B C

FIG. 4

Case 2. A and B. Roentgen ray September 29, 1924. Central area rarification, upper aspect pathological fracture present. Condylar aspect of femur involved and area of rarification extends into joint cavity. C. Roentgen ray October 2, 1924. Area of rarification much greater, joint cartilage eroded and tumor tissue invading joint.

left lung. Patient died three years to the day from the time first seen. No postmortem examination was obtained.

Case 2. Woman, age thirty-six years, was first seen October 1, 1924. At this time she complained of a sore, swollen and painful left knee joint. The illness began early in May 1924, when she was struck by an oven door and sustained a mild injury to the left knee. Following this injury the knee was sore and slightly swollen for several days. The latter part of June 1924, she sustained a second injury to the left knee. Again the trauma was trivial but the knee remained swollen and sore for a week. At the end of this time she consulted her physician about the knee and was given medicine which did not help; the swelling and pain gradually increased. The middle of July she saw another physician. August 5, 1924, the knee was aspirated and the swelling and pain diminished after this procedure. The last of August she fell down several stairs and sustained a supracondylar fracture of the left femur. After several weeks' treatment at home, she was removed to a hospital. In addition to the fracture she was told she was suffering from arthritis. The leg was immobilized in plaster but in spite of this the pain increased. September 15 her tonsils were removed; during the remainder of the month her pain and discomfort increased. October 1, 1924, she was seen by Dr. Chatterton in consultation. Family and marital history was negative. Physical examination was essentially negative except for some loss of weight, soreness of throat and slight elevation of temperature. There was pain, swelling and tenderness of the left knee. The knee was twice its normal size. There was slight local heat but no fluctuation. The tumor was of firm consistency with dilatation of the superficial veins. Any attempt to move the leg was resented. The features were drawn, and the patient complained bitterly of pain in the left knee. The throat was slightly injected; tonsils had recently been removed. Blood showed moderate secondary anaemia. Blood Wasserman was negative. Urine, negative. Roentgen ray examination, on September 29, showed a supracondylar fracture of the left femur. Below the fracture was an area of rarification about the size of a dollar. Roentgen ray examination October 3, showed the area of rarification much increased, the shaft distended, the joint cartilage broken and the tumor substance invading the joint cavity. Immediate amputation was advised and several days later a high supracondy-

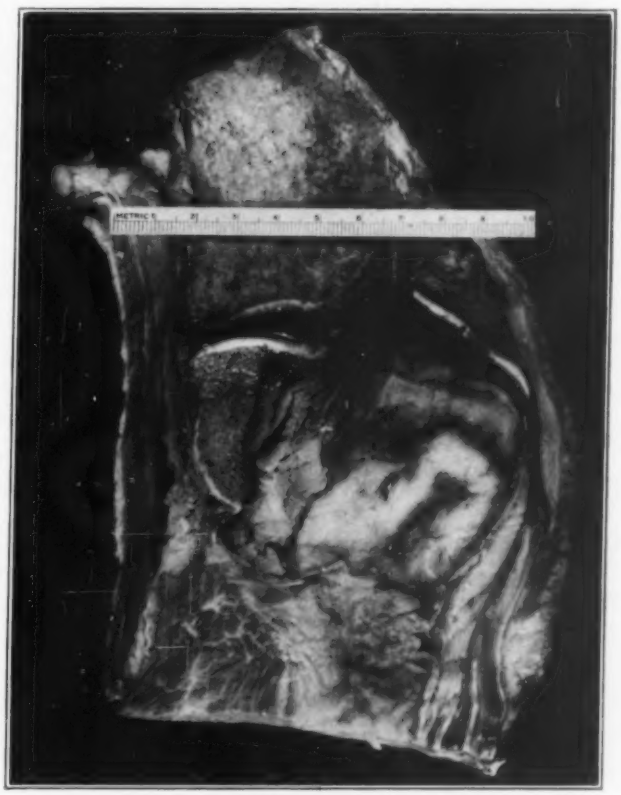


Fig. 5

Case 2. Gross section after amputation. Central tumor involving condyles of femur, especially lateral condyle; joint cartilage eroded and tumor tissue extending into joint.

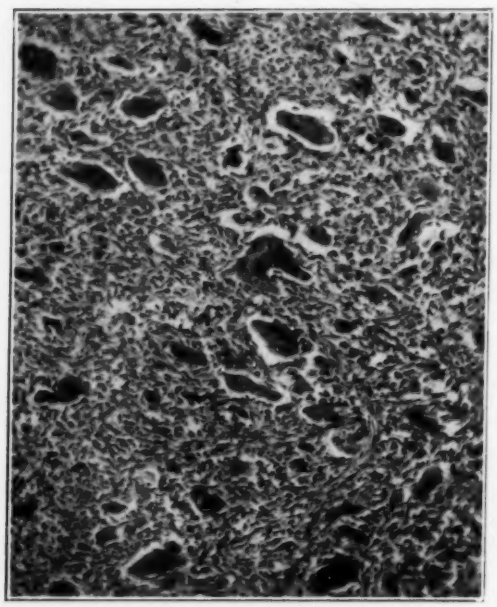


FIG. 6

Case 2. Microphotograph. Numerous foreign body giant cells scattered throughout fibrous tissue stroma. No evidence of malignancy. Diagnosis: Benign giant-cell tumor.

lar amputation was done. The postoperative course was normal. Doctor Bell's report of the microscopic examination reads, "Benign giant-cell tumor". The tumor was of firm consistency, a portion of the joint cartilage was eroded and the tumor had invaded the joint cavity.

Discussion of Case 1: There are certain features that suggest a benign growth that later became malignant. The age of the patient, thirty years; duration of disease, eight years; physical and roentgen examination, all favored benign growth. If one accepts Codman's roentgen criterion of a benign giant-cell tumor, then this particular case seems to fall in nicely: A central tumor of the lower end of the femur; the shadow gives the impression of inflation, the cortex is distended and the growth spherical; the condylar aspect of the femur is markedly involved and the diseased area encroaches upon the joint cartilage. These conditions are of importance in the diagnosis of a giant-cell tumor.

The roentgen shadow over a period of three years remained much the same. The picture taken after the change in the disease shows an entirely different shadow; the cortex is broken and the tumor tissue is invading the soft parts.

On biopsy, in December 1920, the tumor resembled a giant-cell growth; it was filled with yellowish-red debris and bled moderately under the curette. Microscopically, it was diagnosed a benign giant-cell tumor.

The clinical and roentgen course after 1920 resembled those of a benign growth. The patient seemed to be improving. She sustained a mild injury to the knee in the summer of 1922, when she fell to the ground; other than this there was little or no trauma. In September 1923, a definite change took place; intense pain, swelling of the leg, loss of appetite and weight developed, and the joint was extremely tender and painful.

An amputation without exploration was made. A few weeks later the patient died from pulmonary metastasis. Dr. Bell reported the primary tumor to be a malignant osteogenic sarcoma.

Error in diagnosis at biopsy in 1920 must be granted because the slides and the gross have been destroyed. The subsequent course and pictures up until September 1923 do not suggest malignancy. The

probable transition due to trauma, as held by Stone and Ewing, must also be granted, but our operative trauma was the minimum. The patient sustained several strains during 1921 and 1922, but her condition seemed to be improving. During the greater part of the three years following biopsy, the leg had been immobilized or protected. Trauma in this case was very moderate.

Discussion of Case 2: The clinical course and age is suggestive of a malignant tumor. When first seen the illness had lasted four months. During this period a pathological fracture was sustained, which according to Bloodgood is more common in bone cysts and malignant tumors than in giant-cell tumors.

The roentgen picture of October 3 showed that in three days the growth had extended and invaded the joint cavity. The patient appeared sick, had lost weight, the pain was intense, all suggestive of an aggressive type of central growth. Microscopically the tumor was a typical giant

COMPARATIVE STUDY OF CASES 1 AND 2

| | | Case 1. Miss D. | Case 2. Mrs. C. |
|---|---|---|---|
| 1. | Sex | Female | Female |
| 2. | Age | Thirty years | Thirty-six years |
| 3. | Knee | Left | Left |
| 4. | Family history | Negative | Negative |
| 5. | Pathological fracture | Suggestive when first seen. | Definite when first seen. |
| 6. | Previous diagnosis and treatment. | Rheumatism; Anti-rheumatic; tonsils removed.<br>Sprain; rest. | Arthritis; Anti-rheumatic and aspirated; tonsils removed.<br>Fracture: Treated at home; fixation. |
| 7. | History of trauma preceding onset. | No history, knee never just right.<br>Definite trouble in 1915. | Mild definite trauma; repeated month after first injury. |
| 8. | Duration | Knee weak long as remember; definite onset 1915, 5 years' duration when first examined in 1920. | Four months' duration when first seen. |
| 9. | Symptoms:<br>a. Pain | Pain present and mild for five years at least; moderate when first seen in 1920; severe in fall 1923. | Fairly severe at time of trauma in May; apparently well in several days; again severe after trauma in June; then moderate but continuous. Severe after fall in September; very severe when seen. |
| | b. Swelling | Moderate since 1915; more marked after fall in 1920; great after illness 1923. | Gradual increase after date of first trauma; more pronounced after fracture. |
| | c. Tenderness | Tenderness in 1920; severe 1923. | Present since second trauma; severe since fracture. |
| | d. Local heat and dilatation of veins. | Local heat and dilatation of veins marked after illness 1923. | Local heat and dilatation when seen September, 1924. |
| | e. Fluctuation | No fluctuation. | No fluctuation; joint fluid had been aspirated. |
| | f. Atrophy | Atrophy thigh and leg fairly marked. | Atrophy moderate. |
| | g. Disability | Crutches off and on since 1918. | Patient recumbent when seen. |
| | h. Temperature | None first seen 1920; definite elevation temperature, fall 1923. | 101° on first examination. Patient, however, had tonsils removed week previous; throat still sore. |
| | i. Wasserman | Negative. | Negative. |
| | j. Blood examination. | Secondary anaemia. | Secondary anaemia. |
| | k. Urinalysis | Negative. | Negative. |
| 10. | Roentgen ray | Central tumor lower end of femur.<br>Distention shaft, rarification involving condylar aspect femur and encroaching upon joint. Lines trabeculation present throughout tumor mass. Suggestion old fracture present.<br>Picture remained about same during 1920, 1921, 1922, until fall of 1923.<br>October, 1923, cortex broken; tumor tissue invading soft parts. | Central tumor lower end of left femur. Area rarification, September 29, size of dollar; shaft not distended greatly. Definite pathological fracture just above area rarification.<br>Roentgen ray, October 3, four days later, marked progression, shaft markedly distended; joint cartilage eroded and tumor invading joint cavity. |
| 11. | Diagnosis | Clinically<br>Biopsy { gross<br>microscopic<br>Roentgenologically } 1920, Benign giant-cell tumor. | Clinically<br>Roentgenologically } Probably malignant osteogenic sarcoma. |
| | | Clinically<br>Roentgenologically<br>Microscopic } 1923, Osteogenic sarcoma, malignant. | Microscopic<br>Gross } Benign giant-cell tumor. |

cell. This case represents, we believe, the borderline type: the clinical and roentgen pictures suggest malignancy, but microscopically the tumor is benign.

SUMMARY

Case 1 suggests that occasionally true giant-cell tumors do undergo malignant changes even where operative interference and trauma have been mild.

Case 2 illustrates the borderline aggressive type of giant-cell tumor. Clinically and roentgenologically this was more suggestive of malignancy than Case 1. Microscopically the tumor is benign.

These cases with others reported, suggest that at times difficulty and peculiarity is encountered in the diagnosis and behavior of giant-cell tumors.

We wish to acknowledge our thanks and appreciation to Dr. E. T. Bell of the University of Minnesota.

BIBLIOGRAPHY

1. Bloodgood, J. C.: The Diagnosis and Treatment of Benign and Malignant Tumors of Bone. J. Radiol. I, 147, March, 1920.
2. Coley, W. B.: Prognosis in Giant-cell Sarcoma of the Long Bones Based upon the End Results in a Series of Fifty Cases. Ann. Surg., LXXIX, 561, 1924.
3. Stone, W. S. and Ewing, James: An Unusual Alteration in the Natural History of a Giant-cell Tumor of Bone. Arch. Surg., VII, 280, 1923.
4. Morton, J. J., and Duffy, W. C.: A Clinical and Pathologic Study of Ten Bone Tumors. Arch. Surg., VII, 469, 1923.
5. Codman, E. A.: Bone Sarcoma. New York. Paul B. Hoeber, Inc. 1925.
6. Meyerding, H. W.: Benign Foreign Body Giant-cell Tumors in Long Bones. J. Am. Med. Assn., LXXXIII, 1323, Oct. 25, 1924.

# THE UNDERWATER GYMNASIUM AS AN ADJUNCT TO ORTHOPAEDIC SURGERY*

BY C. L. LOWMAN, M.D., F.A.C.S., LOS ANGELES, CALIFORNIA

The treatment of all manner of conditions in pools is a fact which dates back to remote antiquity and even the specific use in our own field has long been used and advised in isolated instances.

We have chosen this title in order to emphasize to you the fact that our use of the out-of-door pool in connection with muscle re-education is specifically as stated. The pool is in no sense a swimming pool. The cases treated in it come by special appointment, on assigned days, at certain hours, and treatments are graded in dosage, limited in range and strength, as conditions indicate. The technicians are all graduates in Physical Education, as all physiotherapists should be, and are competent to teach swimming when desired. It must be remembered, however, that the cripple in swimming, as in walking, desires progression and will use any musculature available to attain that end. Consequently the use of muscles already strong, without supervision, would do more harm than good.

For the past year we have been treating various types of cases in a pool specially equipped to handle orthopaedic cases, notably poliomyelitis both recent and old, cerebral palsies—commonly classed as "spastics"—congenital hips, posture cases, etc.

The pool is three feet deep with two and one-half feet of water divided into two sections: the larger about eighteen by twenty-two feet, the smaller ten by fifteen feet, one used for salt water and one for plain. The larger contains approximately five thousand gallons, the smaller three thousand.

While swimming strokes are used and taught as a definite part of the muscle re-education program, they are always adapted to the special need. For instance, in deltoid paralysis, the active stroke is out and up which propels the body in the reverse direction from that of the usual one. For localized muscle training the patients are placed on the submerged plinths, which are six feet long, two and one-half feet high at head, and slope down to twelve inches high at foot, the surface being eighteen inches wide at top and ten inches wide at bottom. They are made of concrete with a row of ring bolts along the side into which are snapped loops, which pass around each leg as perineal straps to keep the body from slipping down. The head is thus held just out of water and the fear of submergence is removed. Down the middle of the plinth is placed a row of one-inch holes, six inches apart, into which a post can be inserted for the child to straddle. It can be padded by wrapping a towel about it or may be shaped as desired. When the post is used a little more freedom of leg movement is allowed than with the loops.

*Read before the meeting of the American Orthopaedic Association at Atlanta, April 28, 1926.

At the foot is a series of parallel holes into which pegs supporting a foot-board are inserted. Two holes at the top corners, two inches in diameter and six inches deep, are occasionally used to hold the shaft of a beach umbrella, although one is seldom used except in the hottest weather. Along one side of the pool is a concrete bench one foot wide and one foot high, upon which simple foot cases sit while doing foot exercises, or this may be used for rest by those who swim back and forth across the pool.

For the use of the extensively paralyzed—practically helpless—cases the "Bubble Boat" has proved a godsend. It is an English surf boat called by the children the "Bubble Boat" because it is supported by three large rubber balls about one foot in diameter. Through the middle extends the bamboo supporting framework. This frame is about five feet long and two feet wide at the top and fourteen inches at the bottom. Between the parallel bars are suspended two canvas slings which support the body just below the surface.

For work in the pool, the technicians wear high, light-weight hunter's "waders", and an orderly assigned to the Physiotherapy Department carries the patients from the dressing tent into the pool.

From a general standpoint the value of the pool lies in the high degree of enthusiasm and interest that is aroused in the patients. They can hardly wait till the next day for treatment and any who ever have been in the water before their affliction look forward with keen anticipation to the time when they can start.

We find that these, as any other emotions, call for expression and as expression is always evidenced by motion, it requires no urging or further stimulus to action. This interest does not flag and the fact is that when these children finally get so that they can swim they are elated, because at last they can do something that others can do. Their helplessness becomes less acute, they work with renewed effort and interest and the change from the tiresome bed to the pool is a welcome relief.

FIG. 1

FIG. 2

Pool dry, showing inclined plinth.

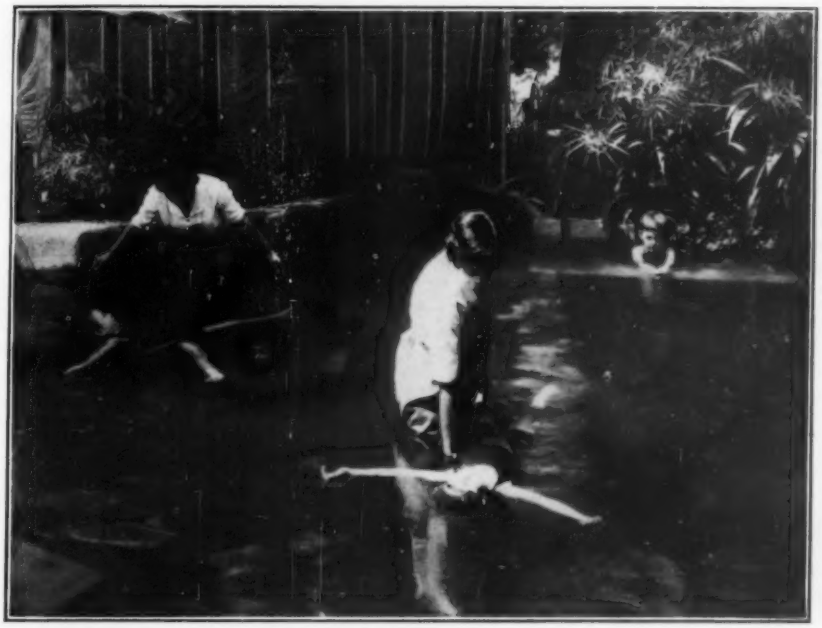


FIG. 3
Pool filled. Technicians and patients.

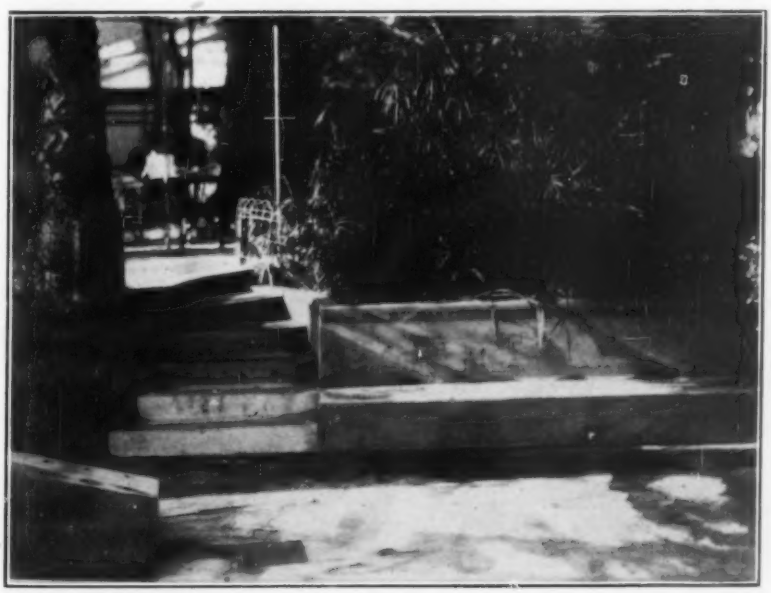


FIG. 4
Showing dry pool and concrete bench.

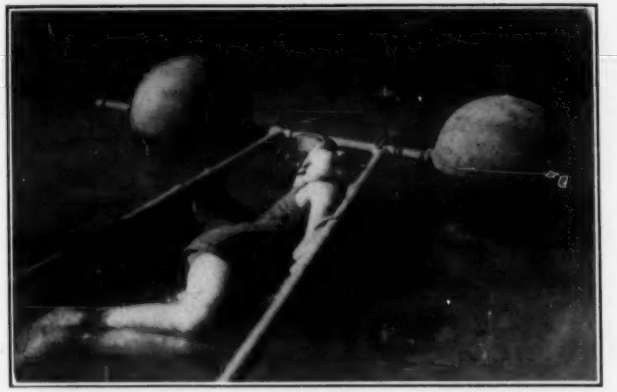


FIG. 5

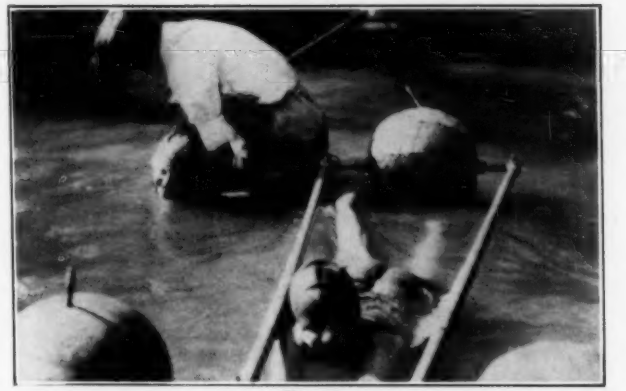


FIG. 6

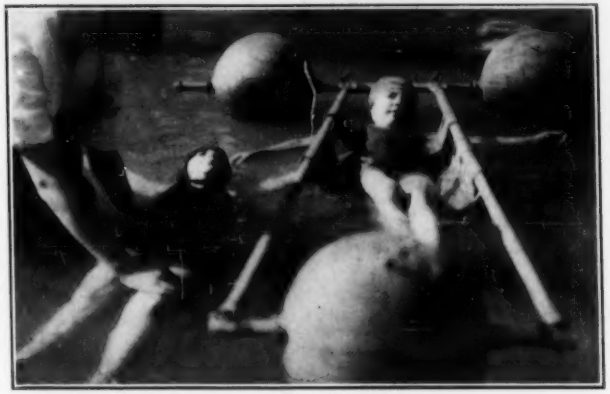


FIG. 7

FIG. 8

Figs. 5, 6 and 7. English surf boat for helpless cases and beginners.
Fig. 8. Child submerged beside plinth. Note holes for perineal posts.

FIG. 11

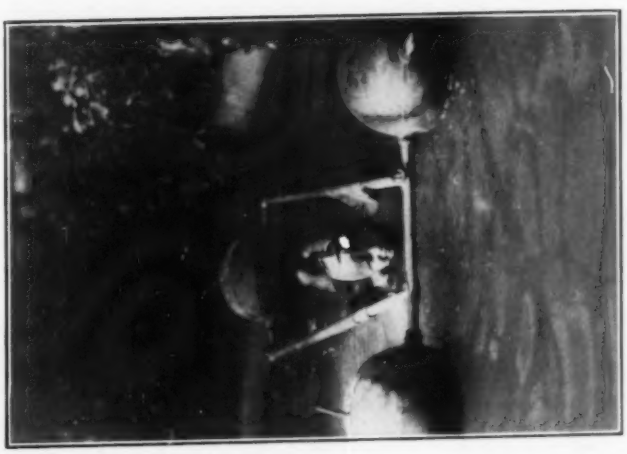


FIG. 10
English surf boat or "Bubble Boat".

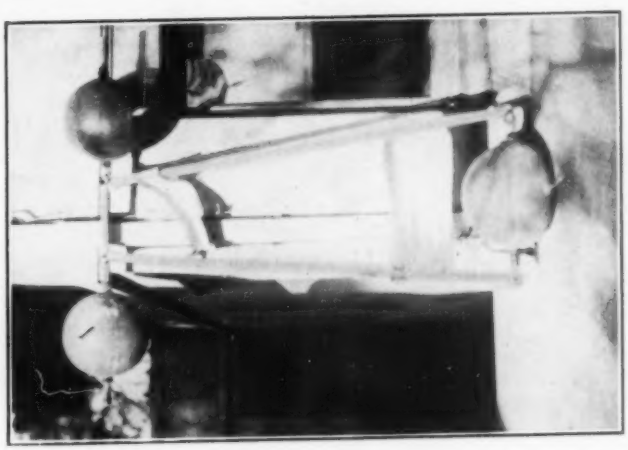


FIG. 9

The water is heated by live steam and we find the optimum temperature for most cases to range from 88° to 91° F. The spastic group including all hyperactive cases require a higher temperature—from 95° to 100°, in which better relaxation and coordination is obtained. Warmer water than used in regular swimming pools is necessary because these frail, inactive children chill more readily than the normal, and, furthermore, weak muscles cannot function well when cold. With the added precaution of watching the length of treatment, no bad reaction from chilling has been noted in any cases during the year the pool has been used—even in midwinter, for it has been used throughout our winter months. Ten to thirty minutes is the average time for all except a few of the more rugged and old chronic cases, in whom the more vigorous development of trunk muscles is desired. In the older chronic poliomyelitis cases the children with leg involvement say they are steadier because of the treatments, which is due to increased tone and power of gluteals, quadratus lumborum and lower back muscles.

The sequence of treatment is: first, the fear of water is overcome; second, every one is taught to breathe properly; third, each one is taught to float both prone and supine; fourth, emphasis is added to the work of the parts involved—leg or arm, hands or feet, as indicated.

## CASE OBSERVATIONS

*Recent Poliomyelitis Cases:* We have started underwater treatment in these cases several weeks earlier than ever before, beginning as early as the

FIG. 12
Showing the plinth with foot-board in position. Pool dry.

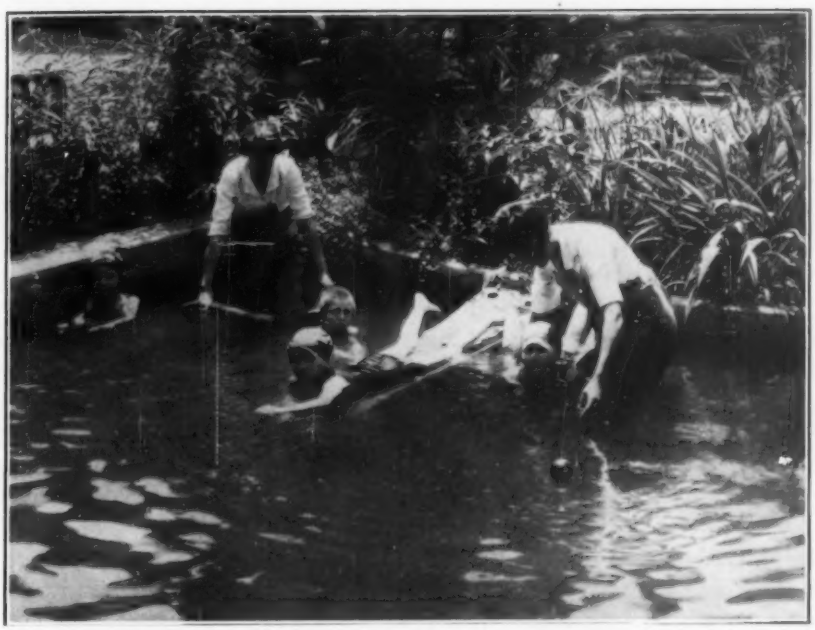


FIG. 13

sixth week or immediately after a reasonably safe quarantine, even while some muscle soreness still existed. While we have not treated a comparative group at the same time by other methods, we feel from very extensive experience that, following the treatment in the pool, the soreness and stiffness seem to disappear more quickly. We do know, however, that in the water the movement can be started earlier with greater range, before spasm from soreness ensues, than can be done with bed treatment. The morale of the patient is decidedly better, because the inhibitions established during the early stage of acute soreness when the child dreads handling, are more readily overcome. In the water the children rapidly relax and lose their fear and probably the sensory threshold is raised by the development of other more powerful stimuli which claim the attention.

Under the former treatment of early splintage for physiological rest, baking, massage and muscle training were not started till soreness disappeared, the period of inaction averaging about ten to twelve weeks. The mental resistance to movement in the first four to eight weeks, plus the increased sense of comfort from lying perfectly quiet, with the added pathological diminution of function and nutrition, make an obstructive barrier which is extremely difficult to overcome. When the actual sense of feeling of motion thus becomes lost it is expecting a good deal of the small patient, especially, to abstractly "think" the impulses down to the various muscles.

In the water, however, the contact with it, stimulating immediate bodily movement physiologically through the myriads of tactile end organs, produces a far greater and more natural stimulus to movement,

which is accomplished more readily without strain because the gravity load is removed. The children sense this more readily than when a technician carries the gravity load by lifting the part with her hand.

Probably there is awakened a natural desire to move in the water as a response to racially old instinctive tendencies, consequently lessening the need of abstract mental effort required to activate the motor apparatus plus, possibly, an instinctive and inherent effort toward self-preservation, which any non-amphibious creature demonstrates when put in water.

A most interesting phenomenon constantly observed by the technician is the ability to float. A wholly paralyzed leg will sink to a depth limited by the natural range of hip joint ligaments but this depth varies in definite proportion to the amount of muscle involvement. When and as the muscle power returns the distance from the surface decreases and the position assumed is more like the unafflicted leg or arm which readily floats. The physics of this we have not yet solved, although an actual difference in weight must exist because of atrophy, but whether this alone completely explains the phenomenon we do not know. It is a consistent finding however, and hence has become of prognostic value.

During the past year we have treated ten cases of poliomyelitis in the early stages and on a basis of our experience there has been a more satisfactory degree of improvement in less time than by any previous method we have used.

It must be remembered, however, that it does not wholly replace the regular muscle training in the gymnasium or in bed, which is decidedly more disciplinary and regulatory and should be resorted to as soon as all soreness has disappeared and muscle "come back" is evidenced.

In chronic or old poliomyelitis cases the pool treatment should be used for general toning up of the body as an adjunct to the regular gymnasium work, for, from the improved body control, it makes better use of arm and leg than does simple gymnasium work alone. The most prominent result with this group, however, is the psychological effect upon the children of finding that they can begin to compete in an active sport with their more fortunate fellows and feel less "out of it" socially.

Congenital and other hip joint conditions are handled with increasing satisfaction, especially because of the lessening of fear of movement after casts are removed and motion instituted. The terrifying apprehensiveness shown by these cases after the long imprisonment in casts for fracture, traumatic epiphysitis or congenital hip is one of the most obstinate factors militating against the reestablishment of function, with which the physiotherapist and surgeon have to contend.

This factor is well illustrated by the case of Laura S., a congenital hip case. She was of the repressed type, very tense, nervous, apprehensive, never smiled, was strongly suspicious, reacting rigidly against all efforts at passive or active passive movement of legs. In the pool she quickly gained confidence, learned to swim dog fashion, face down, and walking in water was much improved over previous efforts. Motion was established early and soreness lessened more rapidly. Before discharge she always wore a smile and her morale was one hundred per cent. better.

A case illustrating the poliomyelitis group is Mildred W., aged sixteen. She suffered an acute attack, three months before coming to us. The patient presented total paralysis of both legs and of the pelvic structures, with both feet in mild equinus. She was still so sore that she screamed when the Achillis were tightened in testing dorsiflexion. Her parents reported absolute dejection and discouragement, bordering on melancholia. She had talked about suicide. She was terribly apprehensive, fearing any effort at handling, especially while casts were being put on for correction of toe drop. Feet were straight in six weeks and braces put on. Treatment in the pool was then started and almost immediately soreness began to disappear. Morale improved spectacularly and motion began to return satisfactorily.

In concluding let me say that as a result of our experience we are planning the construction of a special Hydropathic Unit with an indoor pool connected with this out-of-door one, so that they may be used separately or as one. Convenient dressing rooms for patients and technicians will be arranged and a waiting room for patients. We expect to extend this line of treatment to many other conditions.

## DISCUSSION

Dr. H. P. Galloway, Winnipeg, Man.: The thing that has appealed to me in this method is the attention to detail. I was impressed this morning with the way Dr. Swaim handled the details of his cases and now I am impressed again in listening to Dr. Lowman. The attention to details that is given the patients with orthopaedic deformities in Dr. Lowman's clinic has a very large bearing on the success achieved. This demonstration this afternoon is an extremely interesting one to me and it seems to me this method of physical education deserves a larger measure of attention. Just as an increasing effort is being made everywhere to impart education to children in a pleasing way, instead of having it poured into them like unwelcome doses of castor oil, so the great advantage of this form of physical training is that the patients enjoy it and look forward to it. It is not something unpleasant that they have to take at the hand of the doctor. They can hardly wait from one treatment to another. They are doing something that they themselves regard as play.

Dr. J. P. Lord, Omaha, Nebraska: It has been with great satisfaction that I have used the water tank of the ordinary farm. I want to give testimony to the advantages of this method of exercise. All that is necessary in the farm homes where there are no facilities is to employ the ordinary stock tank, which may be from twelve to sixteen feet in diameter. The children take to this so readily that it is difficult to keep them out of it. A supplemental advantage is that of heliotherapy, for some of the children come back the color of Indians. We do not have to wait until we have special places with such wonderful surroundings for the application of the water treatment. It can be utilized on every farm or even in the city where a stock tank of galvanized iron is made available.

# THE OPERATIVE LENGTHENING OF THE TIBIA AND FIBULA*

BY LEROY C. ABBOTT, M.D., F.A.C.S., ST. LOUIS, MISSOURI

An extreme degree of shortening in one leg caused by severe disease of the hip or knee joint, fractures, or infantile paralysis is a condition not infrequently seen in any large clinic devoted to the treatment of crippled children. This difference in length of the lower extremities produces a marked limp, a downward tilting of the pelvis and a postural curvature of the spine, all of which may lead to serious disability. In the group of cases referred to we include only those in whom the shortening is one and one-half inches or more and in whom other causes of disability, such as deformity, have been removed or have never been present.

The application of a lift to the shoe in such cases is objectionable, for its height alone is unsightly and its weight is often a source of marked discomfort. This is particularly true in extensive paralysis of the limb due to anterior poliomyelitis, and many patients so afflicted discard the lift as awkward and cumbersome and prefer to walk with crutches. They express themselves as "willing to go through a good deal" if any reasonable assurance can be given that the asymmetry of the lower extremities can be reduced or equalized.

Other methods of treatment which have been used are stimulation of growth at the epiphyses and operations on the bones which aim either at shortening the sound leg or lengthening the shortened leg. The first method has generally failed to give good results while the latter have not been reported in any large group of cases. A review of the literature, however, does show that leg shortening and leg lengthening operations have been attempted with varied degrees of success. No one surgeon, however, seems to have had a large experience with either method.

In 1905 Codivilla[1] described a method of lengthening of the long bones of the lower extremity which consisted of osteotomy of the shortened bone and traction by a nail driven through the os calcis. In twenty-two cases of old fractures of the femur and tibia the gain in length averaged from three to eight centimeters. In 1912 Freiberg[2] used the Codivilla method with a modified traction apparatus in a boy, nine years of age, with a fractured femur of five weeks' duration. The shortening of two and one-quarter inches was reduced to one-half inch. Magnuson[3], in 1908, published the results of his leg lengthening experiments on animals. From these he concluded that it was probable that from two to three inches could be obtained in a bone as long as the human femur without producing serious injury to vital structures. In 1913 Ombrédanne[4], in a case of shortening,

*From the Shriners' Hospital for Crippled Children, St. Louis, Missouri.

did an oblique osteotomy of the femur and applied an external screw extension device to the fragments which was extended from day to day. The gain in length was three centimeters. Tunstall Taylor[5] and Fassett[6] attempted to lengthen the femur by osteotomy and adhesive traction subsequent to operation. The results were not encouraging.

Putti[7], in 1921, published his paper on "Operative Lengthening of the Femur". His method differed from that used by others in that traction and countertraction were taken directly upon the bone. Furthermore, he emphasized a point of fundamental importance, namely, that the elastic resistance of the soft parts must be overcome by a gradual and continuous form of traction.

The apparatus which he devised, called an osteoton, consists of two large metal pins which are fixed in the proximal and distal fragments. A telescoping tube, in which is contained a strong spring pressed by a screw, is fitted by two metal sockets to the projecting ends of the pins. The amount of force used in traction and the actual length obtained is read by a scale which is engraved on the tube. The apparatus remains in place for thirty days with no other fixation of the fragments during this period. It is then removed and a plaster-of-Paris spica is applied. In all cases union was somewhat delayed.

Ten cases of shortening due to old fractures of the femur were treated by this method and an average lengthening of three to four inches was obtained. One case demonstrated lengthening beyond normal proportions. In only one instance was there pain and this was referred along the course of the sciatic and crural nerves.

From the above review of the literature we can conclude that the actual lengthening of the leg by operation is a practical procedure which, however, has been used largely where the shortening is due to old fractures. Very few successes are recorded where the shortening has been due to other causes, such as infantile paralysis. It would seem that the problem here is quite different because we are dealing with cases in which the desired length has never existed. The work of Codivilla, however, is of importance because he showed the great value of skeletal traction. Putti carried this work still further by showing that the best results are secured when traction and countertraction are taken directly upon the bone. Furthermore, he showed that the attempts to gain length at the time of operation were usually futile, it being by far preferable to use traction which was continuous over a long period of time.

My own interest in the problem of lengthening the leg came after hearing Putti read his paper before the Orthopaedic Section of the American Medical Association. Later, I attempted lengthening of the femur in two cases which were admitted for treatment at the University Hospital, Ann Arbor, Michigan. The first case was a boy twelve years of age with two and one-half inches of shortening due to a malunited fracture of the femur, while the second case was a boy of fifteen with three inches shortening of the femur due to infantile paralysis. In each case a Z-shaped oste-

otomy of the femur was performed and traction was secured by a Steinman pin placed through the lower part of the shaft of the femur well above the epiphyseal line. The limb was supported on a Thomas splint and countertraction was obtained by suspending the ring against the ischium by means of an overhead bed frame. Weight up to forty pounds was employed. In the fracture of the femur a gain of two inches was secured, while in the case of infantile paralysis a gain of one and one-quarter inches was obtained.

More recently I have become interested in those cases of marked shortening of the leg due to anterior poliomyelitis. In many of these children disability is increased by the presence of deformities, but even after these are corrected there remains a serious handicap due to the shortening. The application of a lift often fails to give the relief desired and therefore more radical procedures are justifiable if they give reasonable hope of success without entailing great risk.

As the first few cases which I saw were those where shortening was largely confined to the tibia and fibula, a plan was devised for lengthening of these bones. It was based on the fundamental principles of traction and countertraction emphasized by Putti in his article on "Operative Lengthening of the Femur". One feature of his work to which I gave considerable thought was that in all of his cases union was somewhat delayed. Was this because a long time was required for the formation of sufficient callus to fill in the gap separating the fragments? Did not a lack of apposition and accurate contact of the fragments contribute to further delay in union? To the best of my recollection the pictures which he showed indicated a very considerable tilting of the fragments. Furthermore, it is to be remembered that during the lengthening period the osteoton was the only apparatus used to support the limb. While it is conceivable that this might prevent lateral tilting of the fragments, yet it could hardly prevent their displacement in an anteroposterior direction. It seemed to me, therefore, that it was highly desirable to employ an apparatus which would combine all the advantages of Putti's osteoton but would, in addition, maintain contact and accurate alignment of the fragments. With these fundamentals in mind we argued that if an equal traction force was maintained on both sides of the leg, lateral tilting of the fragments would be prevented, while good alignment in the anteroposterior plane could be secured by the use of what has been termed "stabilizers". The description of the apparatus which we use can be given best under the following headings:

1. Two steel drills.
2. Two screw extension pieces.
3. Two stabilizers.
4. A Thomas splint and an adjustable foot-piece.

The drills are made from two pieces of drill rod, each nine inches in length and three-sixteenths of an inch in diameter. They have very sharp drill points so that they will readily engage in the cortical bone while the opposite ends are squared off to fit in the ordinary drill chuck. The regulation

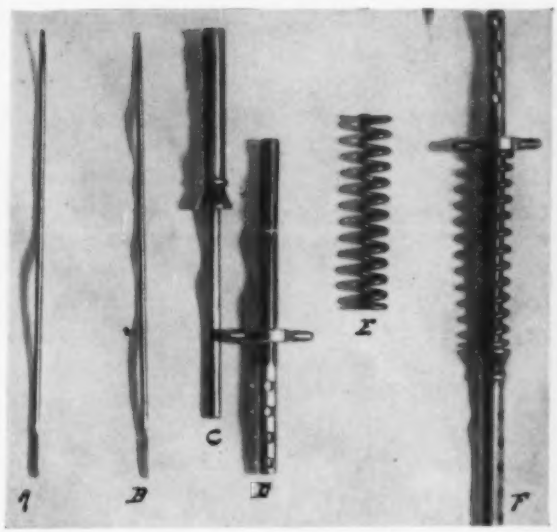



FIG. 1

Steel drills and screw extension pieces. A and B—Steel drills 9 inches in length and $\frac{3}{16}$ of an inch in diameter. C—Brass tube with handle, flange and machined-down part which telescopes within the inner half of brass tube. D—The enveloping part is cut with threads and holds a thumb screw. E—Strong coil spring. F—Screw extension piece assembled with coil spring fixed between flange and thumb screw.

FIG. 2

Pins inserted in tibia with screw extension pieces attached. Note markings indicating method of sectioning the tibia and fibula. The osteotomy of the fibula, however, is usually done in the lower third of the bone beginning above and behind and ending below and in front.

Steinman pins are not used because they cannot be driven through the compact bone and their insertion requires a preliminary drilling of the cortex. These specially constructed drills are turned through the bone and left in place for attachment to the extension pieces. The trauma to the tissue is thus minimized and the risk of infection is proportionately diminished.

Two screw extension pieces are essential in order that traction may be applied to both sides of the leg. They were designed by Mr. P. Bauer, Chief Mechanician, Washington University Medical School. They are simple, durable and can be sterilized. Each piece consists of two brass tubes which, for purposes of description, may be divided into inner and outer segments. The inner segments telescope upon one another while the outer segments, or handles, fit over the projecting ends of the pins. There are four holes in each handle which allow for adjustment of the apparatus to varying distances which may separate the pins when they are placed in legs of different lengths.

The inner half of one tube is machined down so that it is separated from its handle by a flange. This machined-down part telescopes within the inner half of the other tube. The outer surface of the enveloping tube

is cut with threads and holds a brass thumb screw. Between the flange on one piece and the movable thumb screw on the other a strong coil spring is placed (Fig. 1). When the apparatus is put together and the handles fixed to the ends of the pins, the thumb screw is tightened and the spring is forced directly against the flange. This causes a separation of the two pins and therefore a definite increase in the length of the leg. At the same time a tension on the spring is created which furnishes a continuous form of traction (Fig 2).

Though the screw extension pieces control lateral deviation of the fragments, they do not prevent their displacement in an anteroposterior direction. For this some form of apparatus to hold the pins in the same horizontal plane is necessary. For this purpose mechanical appliances termed "stabilizers" were designed by our Chief Mechanician, Mr. H. P. Werthmuller. They are two in number, one for each side of the leg. Each consists of a steel rod bent to form a long horizontal segment which lies opposite the leg and two vertical segments which are firmly attached to the lateral upright of the Thomas splint directly opposite the ankle and the knee. The lower, vertical segment fits into a socket which has been welded to the Thomas splint, while the upper has a hook-shaped process which allows it to snap into place.

To the horizontal part two turnbuckles are fastened by adjustable metal cylinders. The upper screws on the turnbuckles have loops which fit over the drill ends. By loosening or tightening a turnbuckle the individual pin to which it is fastened can be moved upward or downward as desired. With each tightening of the thumb screws on the extension pieces the pins have a tendency to tilt and throw the fragments out of alignment. By adjustment of the four turnbuckles the drill rods are maintained in the same horizontal plane and thereby prevent any tilting of the fragments in an anteroposterior direction. The metal cylinders which fasten the lower ends of the turnbuckles to the horizontal bars allow them to slide freely with each increase in length of the leg without, however, losing their efficiency in maintaining apposition and alignment of the fragments (Figs. 3 and 4).

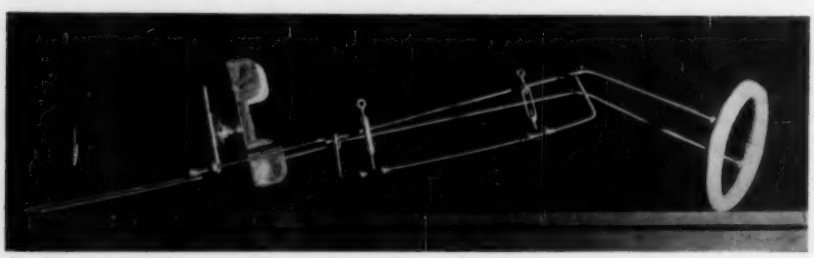


FIG. 3

Thomas splint, adjustable foot-piece and one of the "stabilizers". The turnbuckles are held at their bases by adjustable, metal cylinders. Their upper screws hold loops which slip over the ends of the drill pins.

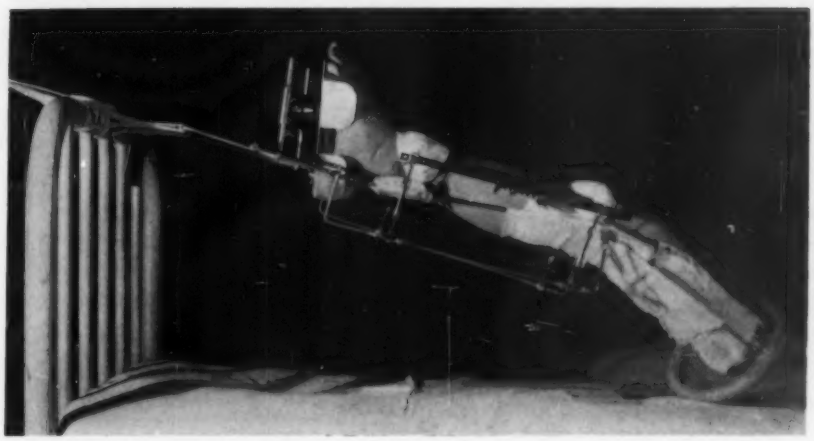


FIG. 4

Photograph of Case 6 with apparatus in place taken after a gain of 1⅞ inches in length had been secured. The four turnbuckle loops are fitted over the ends of drill pins and assist in maintaining alignment of the fragments.

The Thomas splint is of the ordinary type except that opposite the foot it is bent in the form of a rectangle. This facilitates adjustment of the foot-piece.

A specially constructed foot-piece has a metal foot-plate and four lateral flanges, two on each side opposite the forefoot and heel. These flanges are removable and permit of adjustment and adequate inspection of the foot. The foot-plate is fastened to a horizontal strip of steel by means of a thumb screw. This horizontal piece is fixed to the lateral bars of the rectangular part of the Thomas splint by adjustable, vertical uprights. By means of a horizontal slot in the horizontal piece of steel and a vertical slot on the foot plate, each about four inches in length, the foot can be moved upward, downward, laterally or rotated in any direction which is required. Used with the stabilizers, this adjustable foot-piece is of the greatest service in maintaining apposition and accurate alignment of the fragments (Figs. 3 and 4).

## DESCRIPTION OF THE OPERATION

A forty-eight hour preparation of the skin of the foot, leg and thigh is a preliminary to operation. On the operating table a Thomas splint is slipped over the leg and the leather ring pressed firmly against the ischium. Sand bags are then placed between the lateral bars of the splint to give support to the thigh and leg. After application of a tourniquet above the condyles of the femur, the sterile dressings are removed and the skin of the lower thigh, leg and foot is painted with five per cent. picric acid solution in alcohol. Sterile drapings are then placed over the splint and about the foot and thigh.

The various steps of the operation should be carried out in the following order:

1. Lengthening of the tendo Achillis.
2. Osteotomy of the fibula.
3. Insertion of the drill pins.
4. Osteotomy of the tibia.
5. Application of stabilizers and foot-piece.

We have found that it is best to lengthen the tendo Achillis as a preliminary procedure in all patients except those who have a calcaneus deformity of the foot. Otherwise, during the stretching process the tendon becomes taut and forces the foot into equinus.

The method of lengthening used is that employed by Hoke. Through a curved incision on the inner aspect of the lower third of the leg the tendon is exposed and on its posterior surface upper and lower transverse cuts are made half-way through its thickness. On its anterior surface a third cut is made of similar depth and half-way between the two cuts on the posterior surface. Dorsiflexion of the foot allows the bridge of tendon formed by separation at the upper and lower cuts to cover the posterior aspect of the gap left by separation of tendon at the anterior cut. No sutures in the tendon are required. The wound is closed with catgut to the tendon sheath and silk to the skin.

At the junction of its middle and lower thirds the fibula is exposed by a short incision which is placed in front of the peroneal tendons. After vertical division and separation of the periosteum an oblique osteotomy is done beginning above and behind and ending below and in front.

The pins are inserted at the upper and lower ends of the shaft of the tibia. On the lateral aspect of the leg at a point an inch below the tibial tuberosity and one-half inch behind the crest a stab incision is made down to the bone. The drill pin held in the drill chuck is turned through the bone and soft parts until its point bulges against the skin on the inner aspect of the leg. Here a counter-incision is made and the pin forced through the opening until its extremities are equidistant from the inner and outer aspects of the leg. The second pin is inserted in a similar manner about two inches above the level of the internal malleolus. In making the incisions the skin is pulled toward the middle of the leg so that when it is released it will lie loosely above the upper and below the lower pins. This avoids tension on the skin during traction and, therefore, prevents pain. Sterile dressings are then applied to the wounds.

A gentle, curved incision, five inches in length, with convexity facing laterally, is made over the anterolateral aspect of the middle third of the tibia. In order to minimize the injury to the circulation of the periosteum this incision is carried down to the bone without dissection of the soft parts. With a sharp elevator the periosteum is separated from the entire circumference of the bone for a distance of about four inches. With a motor saw two parallel cuts, three and one-half to four inches in length, are made in a vertical direction at the middle of the inner and outer surfaces

of the tibia. These cuts are joined at their upper extremities by a transverse section through the posterior cortex; at their lower extremities by a transverse section through the anterior cortex. This provides a tongue on the lower fragment which lies behind the tongue on the upper fragment. We believe that this helps in preventing a bulging forward of the upper end of the lower fragment in case the foot is not adequately supported. At the middle of the wound the periosteum is incised transversely from its inner aspect, for in this manner we disturb as little as possible its blood supply from the surrounding soft parts. In addition, the deep fascia overlying the muscles on the anterolateral aspect of the leg is incised as far as possible, for it is well known that fibrous structures offer the greatest resistance to lengthening of the bone. The wound is now closed in layers and at its upper end a small rubber tissue drain is inserted. The drain was not used in the first two cases and there was considerable postoperative swelling of the leg. In the few cases where the drain was employed only a moderate amount of swelling occurred. Dressings are then placed over the wounds and the posterior flannel bands adjusted for support of the thigh and leg. The Thomas splint is raised while the screw extension pieces, foot-support and stabilizers are applied and carefully adjusted so that the fragments of the tibia are maintained in accurate alignment. The adjustment of the foot-piece also assists in maintaining good alignment. The Thomas splint is elevated and fixed to the end of the bed. This elevation is essential in the prevention of postoperative swelling.

### POSTOPERATIVE LENGTHENING OF THE LEG

No attempt is made to begin lengthening of the leg until all swelling has disappeared, which is usually between the seventh and tenth days after operation. The drain is removed in forty-eight hours. Daily inspection of the leg under aseptic precautions is carried out in order to prevent projection of the fragments against the skin. A failure to do so may lead to serious complications, as a continuous pressure against the skin by one of the fragments is almost certain to end in sloughing which will usually lead to infection of the bone. In Ombrédanne's case this is what occurred, but he was more fortunate than is usual because despite infection he was able to maintain the length which had been gained. More often, when such complications arise, it is futile to expect a further gain in length or even maintain what has already been secured.

The beginning of leg lengthening is brought about by tightening the thumb screws on the extension pieces an equal number of turns on the two sides. The measurements taken between the ends of the pins on each side of the leg are then recorded. On the second day a few more turns will cause a little further separation of the fragments and again the measurements are carefully recorded. This procedure is carried out daily until we have gained a maximum amount of two inches of lengthening, for as yet we have not felt that it was safe to try to gain more. The average daily

gain is one-sixteenth to one-eighth of an inch and the entire time of traction is about three to four weeks.

It is of the greatest importance to inspect the anterior surface of the tibia in the region of the tibial wound with each application of traction, for with the actual increase in the length of the leg the fragments are almost certain to tilt, usually inward and forward, and in a very short time cause harmful pressure against the skin. This can be prevented at the time of tightening the thumb screws by a simple adjustment of the turnbuckles and foot-piece. In our first case a bulging of the fragments against the skin was noted a few days after operation and it was only after careful adjustment of a rather crude type of stabilizer that we were able to prevent sloughing and exposure of the ends of the fragments. Profiting by this lesson we have gradually carried the stabilizer up to its present stage of development.

A word should also be given here in regard to the care of the foot during the process of lengthening. It should be inspected daily in order to avoid pressure sores, especially where the flanges come in contact with the lateral aspects of the heel. Even with carefully padded flanges harmful pressure is apt to occur. Furthermore, the foot must be adequately supported for if it is allowed to drop the lower end of the upper fragment of the tibia will press against the skin on the anterior surface of the leg. It will be seen at once, therefore, that the apparatus requires the most careful and constant attention in order that the desired length may be obtained without the occurrence of serious complications.

When the desired length has been obtained roentgenograms are taken to check up on the measurements. Care must be taken, however, in the interpretation of the roentgenograms not to arrive at false conclusions. It should be remembered that with the apparatus in place exposures cannot be made with the film in contact with the posterior surface of the leg. Therefore the divergent rays which pass through the ends of the tibial fragments are more widely separated where they strike the film and, consequently, the actual distance between the fragments as seen in the roentgenogram is exaggerated. The degree of error with fixed tube distance is in direct proportion to the distance between the leg and the film and must be considered in the interpretation of results.

We have secured the true measurement, however, by adopting an ingenious plan devised by Dr. A. O. Adams, Assistant Resident Surgeon at our hospital. A piece of steel stamped off by ¼, ½ and 1 inch markings is fixed to the leg by a bandage at the same level as the tibia and then the exposure is made. The roentgenogram will thus show the steel scale with the distances between its varied markings exaggerated in the same proportion as the distance separating the tibial fragments. An ordinary ruler is placed on the roentgenogram and the distance separating the ends of the tibial fragments is marked off. This distance is exaggerated and therefore can be correctly interpreted only by reading it on the steel scale which is exaggerated in the same proportion (Fig. 15). If the steel scale is placed

so that it spans the ends of the tibial fragments then a direct reading can be secured. With the plate taken with the apparatus in place, for every inch of actual lengthening the distance between the ends of the tibial fragments as measured on the roentgenogram is exaggerated one-quarter of an inch. Of course this does not apply to plates taken later on after the apparatus has been removed.

The apparatus remains in place for eight to ten weeks when it is removed in the following manner:

The turnbuckles are removed from the pin ends and the leg raised from the Thomas splint. A long plaster mould is made to cover the plantar surface of the foot and posterior surface of the leg and thigh. This posterior mould is fixed in place by turns of plaster about the foot, ankle, knee and thigh. The screw extension pieces are then detached and the entrance and exit wounds of the pins are carefully cleansed with alcohol and a five per cent. picric acid solution. After giving special attention to cleansing of the parts of the pins which are to pass through the bone they are seized with forceps and withdrawn. They come away easily because they have been loosened by pressure during the traction. Sterile dressings are then applied.

We suspected in our earlier cases that we were losing some length by removal of the pins even when ten weeks had elapsed since their insertion. Therefore, in one case, before the pins were removed, we fixed the fragments by means of a bone pin which was inserted through a small stab incision.

A word should be given concerning the danger of infection of the wounds made by the drill pins. Certainly this danger exists, but it can be minimized by using the most rigid, aseptic technique, by avoiding trauma during the insertion of the pins and by neglecting to dress the wounds until the pins are removed. In all our cases there has been no sign of infection and even in Case 5 where a severe picric acid reaction caused infection of the skin in the region of the pin wounds there was no evidence of infection of the bone. The wounds have healed promptly in all cases, an average time being from ten to fourteen days.

After the removal of the pins, roentgenograms are usually taken at intervals of four to six weeks to show the amount of callus uniting the fragments. From four to five months after operation sufficient callus is usually present to permit the patient to walk with the support provided by a Thomas walking caliper splint. This splint is worn for two months and then gradually discarded. In every case treated by this method callus has filled in the space lying between the fragments in a comparatively short time. This bears out one of the fundamental principles of the procedure which is that during the lengthening process it is absolutely essential to maintain accurate alignment and apposition of the fragments. Otherwise, delayed union is almost certain to occur the same as it would in any fracture with malalignment or displacement. The importance, therefore, of the stabilizer, double extension pieces and foot-support can be thoroughly appreciated.

THE SELECTION OF CASES AND DISCUSSION OF THE PROCEDURE

The operation has been performed in those cases with one and one-half inches or more of shortening which was confined entirely or largely to the tibia and fibula.

With reference to the age of the patients selected we have been somewhat limited in our choice because in the Shriners' Hospital no children beyond the age of fourteen are admitted. We were confronted, therefore, with the problem of doing the operation during the growing period of the child.

The question which naturally arose was, "Would the disproportion in the rate of growth of the lower extremities remain the same after operation and thus produce a further shortening of the affected legs?" A positive answer cannot be given because we do not know all of the factors entering into the production of shortening in infantile paralysis. We do know, however, that the majority of cases of infantile paralysis with marked shortening show extensive paralysis with partial or complete lack of function. Is not this lack of function an important cause of the decreased rate of growth which, extending over a period of years, leads to this pronounced shortening? If so, we could quite logically conclude that we could speed up this rate of growth and prevent, in a measure at least, the occurrence of further shortening by any procedure which would improve the function of the affected extremity. We believe that the leg lengthening operation places the lower extremity in a position for better function and therefore should increase its rate of growth.

Another point of importance is that the maximum growth in the length of the lower extremity takes place at the lower femoral epiphysis. In the cases which we have operated upon there appears to be a minimum disturbance of this important epiphysis, for the greatest shortening was not in the femur but in the tibia and fibula. We should expect, therefore, that the femur would grow at the same rate as before operation, and possibly even more rapidly, due to the improved function of the lower extremity. This improved function might also stimulate the tibia and fibula so that they would grow more rapidly. Even if they fail to do so we must remember that we have added approximately two inches to the length of the leg and it does not seem probable that anything approaching the same amount of shortening which existed before operation would be present at the end of the growth period. The entire question is one which cannot be settled without further study. To decrease the chances of further shortening subsequent to operation, we have thought it advisable to limit the period of growth following it to as few years as possible. Therefore, in the majority of instances, we have chosen those patients who have reached the age of fourteen.

To regard the procedure of leg lengthening as simple in its application would be a serious mistake, for the operation is one of very considerable magnitude. The multiple incisions, the wide exposure of the bone and the

penetrating pin wounds are all grave sources of danger, especially in regard to infection. No one can safely predict the outcome in case of infection, especially if it occurred in the wound which opens the medullary cavity of the tibia over such a wide area. It goes without saying, therefore, that no one should attempt this operation who is not certain that he can maintain the rigid, aseptic technique which is so essential in bone surgery. It has been my custom to consult the parents regarding the advisability of this operation, fully explaining to them the dangers to which the child is to be subjected and emphasizing especially the risk of infection. With such an understanding on the part of the parents and with adequate indications for the operation, we have been ready to proceed.

A second point of importance in regard to this procedure is that no one should undertake it who is not thoroughly drilled in the use of mechanical appliances. The surgeon who has not the time to give for daily adjustment of the apparatus should leave it entirely alone. It is quite impossible for him to carry the procedure through to its successful conclusion unless he can give it adequate time and has a full and complete understanding of mechanical principles. Cases should be very carefully selected and the procedure should be reserved for those who are actually in need of it—those who cannot be relieved of their disability by conservative measures. With the operation in its present stage of development we do not feel that it should become a routine procedure.

## RESULTS

Of the six cases treated by this method one must be regarded as a failure. In this patient, due to a severe picric acid reaction of the skin, we were unable to continue extension of the fragments and the gain was only three-quarters of an inch. The other five were successful, the smallest gain in length being one and one-quarter inches, the greatest one and seven-eighths inches. These increases in length were secured in from twenty-one to twenty-eight days. Union of the fragments sufficient in amount to permit weight-bearing with a caliper splint was present in all of the cases from the fourth to fifth month after operation. In all of the completed cases consolidation of the callus with the fragments in excellent position has taken place in six months.

At no time have we noted any change in sensation of the skin of the foot or leg as tested by pin prick. Furthermore, the stretching process has not caused any apparent change in the circulation. All wounds have healed promptly with no sign of infection except in the case with picric acid reaction referred to above, and even here there was no evidence of infection of the bone.

In the beginning we did not know the amount of length which could be secured within the limit of safety and, consequently, our gains did not exceed one and one-half inches. As we acquired further experience we gained as much as one and seven-eighths inches and we now believe that in the average case this amount should be increased to two inches. Two

inches of lengthening of the tibia and fibula is all that should be required in the majority of cases, for when the total shortening of the extremity is greater, we usually find that part of it lies in the femur. In such cases where further lengthening is required or where the maximum shortening is confined to the femur an operative lengthening of this bone should be the procedure selected. Recently we have devised apparatus for lengthening of the femur which is similar to that employed for lengthening of the tibia and fibula.

FIG. 5

Case 1. Before operation. The shortening of right leg is 2½ inches of which 1½ inches is in the tibia. Note tilting of pelvis and postural curvature of the spine.

## CASE REPORTS

CASE 1. *History.*—B. S., a male, aged fourteen, was admitted to the Shriners' Hospital for Crippled Children on November 7, 1924. At eight months of age he had an attack of anterior poliomyelitis which caused almost complete paralysis of the right lower extremity. His treatment has consisted of massage, exercises and the application of a brace to support the leg in walking. He complained of severe limp and shortening of the right leg. The mother stated that the shortening had produced a curvature of the spine which seemed to be increasing.

*Physical Examination.*—The right lower extremity was flail except for a fair amount of power in the gluteus maximus and biceps muscles. The right foot showed a severe valgus deformity, and the brace which he was wearing failed to hold it in good position. There was a shortening of two and one-half inches of which one and one-half inches was in the tibia and one inch in the femur (Fig. 5).

After discussion with the parents regarding the dangers of an operation to lengthen the leg it was decided that the procedure should be carried out.

*Operation.*—December 8, 1924: A Thomas splint was slipped over the leg and a tourniquet was applied above the condyles of the femur. After the usual preparation, stab incisions were made on the lateral aspect of the upper and lower ends of the shaft of the tibia and the drill pins were turned through the bone. A curved incision was then made on the anterolateral surface of the middle third of the tibia. The periosteum was then separated from the entire circumference of the bone for a distance of about four inches. With a motor saw parallel cuts, four inches in length, were made on the external and internal surfaces of the tibia. These were joined at their extremities by cross-cuts with a Gigli saw through the posterior cortex above and through the anterior cortex below. The fibula was then exposed through the same incision

and sectioned with an osteotome beginning below and in front and extending upward and backward. A transverse incision was made through the periosteum and as much of the deep fascia as could be conveniently exposed. The wounds were closed with catgut to the deep structures and silk to the skin. The stabilizers and foot-support were applied and adjusted so that the fragments of the tibia were held in good alignment.

*Notes.* December 12. — There was considerable swelling of the foot. The foot-piece had failed to give adequate support and the lower end of the upper fragment of the tibia was pressed firmly against the skin. Adjustment of the foot-piece relieved this pressure.

On December 14, the sixth day after operation, the lengthening process was begun by tightening the thumb screws an equal number of turns on both sides of the leg.

December 18. — The stitches were removed and the wound was clean. A small

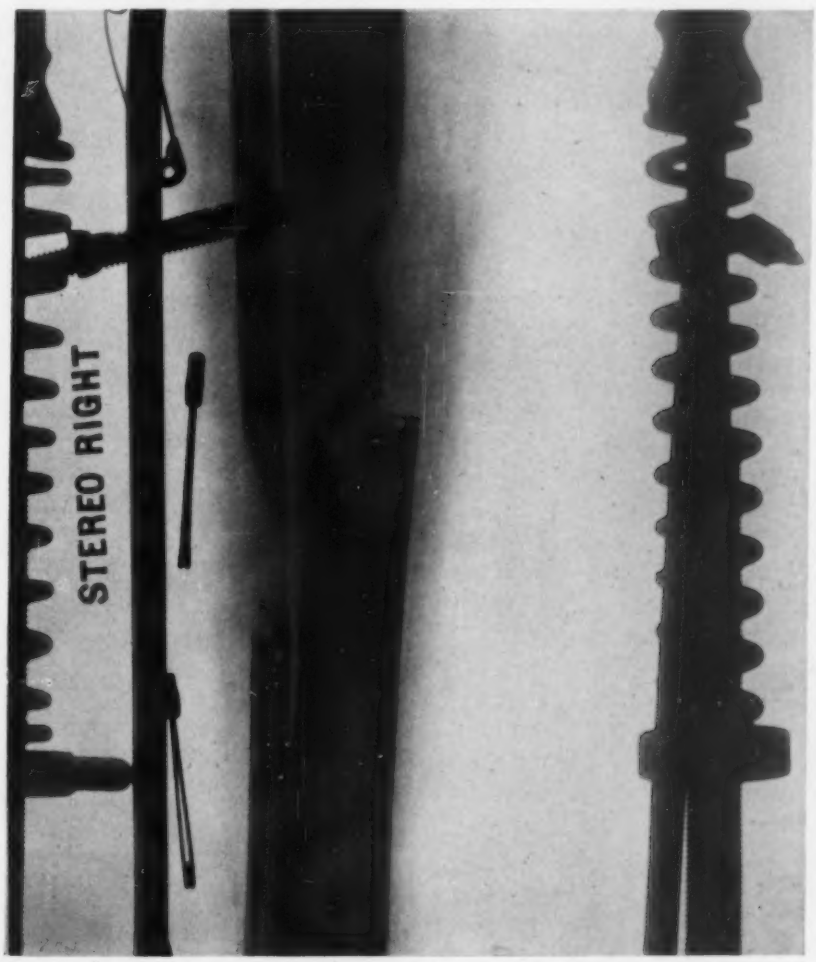



FIG. 6

Case 1. Roentgenogram on the twenty-second day showing a gain of 1¾ inches. This measurement is somewhat exaggerated because with the apparatus in place the film could not be placed in contact with the leg.

blister which had formed over the lower end of the upper fragment of the tibia had entirely disappeared. The thumb screws had been tightened and the measurements showed a gain in length of one-half inch. An examination disclosed the fact that tension on the tendo Achillis caused by the increased length of the leg had forced the foot into equinus.

December 20. — Roentgen-ray examination showed a gain in length of about three-quarters of an inch.

December 29. — With the apparatus in place a Bayer subcutaneous tenotomy was done on the tendo Achillis and the foot brought to right angle dorsiflexion. The measurements at that time showed a gain of a little over one inch.

January 5, 1925. — The stretching had been continued and the measurements and roentgenogram showed a gain of one and one-half inches (Fig. 6).

On January 19 the pins were removed and a plaster-of-Paris cast was applied. There was no evidence of infection of the pin wounds.

February 8. — Roentgenogram showed considerable callus about the fragments.

April 4. — Roentgenograms showed excellent alignment of the fragments and the gap between them was filled in with callus. This was about four months after operation. The plaster had been worn for about three months

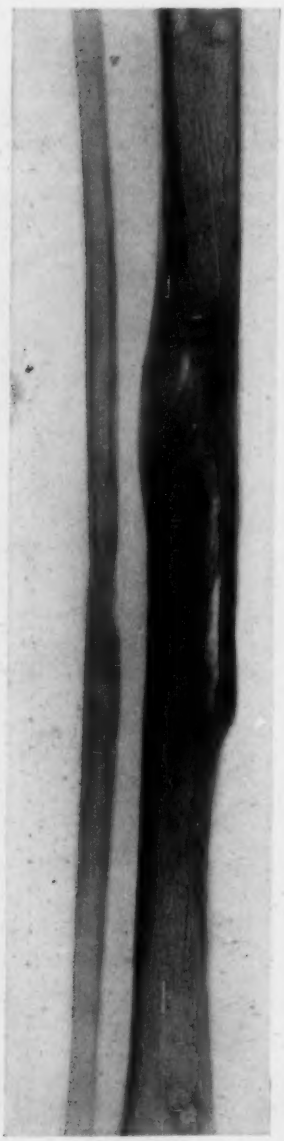


FIG. 7

Case 1. Lateral view five and one-half months after operation. Note callus and excellent alignment of the fragments.

FIG. 8

Case 1. Ten months after operation. Complete consolidation of callus uniting fragments of tibia and fibula.

and the clinical examination indicated union of the fragments. A caliper splint was applied.

On May 19, five months after operation, he was discharged from the hospital wearing the splint. There was solid union of the fragments.

May 27.—The patient returned to the Outpatient Department and measurements showed an inch of shortening which was confined to the femur. Roentgenograms showed good alignment and callus formation between the fragments of the tibia (Fig. 7).

On July 14, the patient was admitted to the hospital for correction of valgus deformity of the foot. A Hoke's stabilizing operation was performed on July 16. The convalescence from operation was uneventful and the wound healed by first intention. He was discharged from the hospital on September 16 wearing a caliper brace and with the foot held in good position. Roentgenograms showed solid union of the fragments (Fig. 8).

November 21.—The patient returned to the Outpatient Department. Measurements showed the tibiae to be the same length (Fig. 9). He was able to walk without a brace, though we cautioned him that it would be best for him to continue to use the walking caliper splint. The mother stated that he walked with less limp and that there was a marked diminution in the curvature of his spine.

December 30.—The patient returned for examination and the foot was held in good position. The measurement of the leg showed a shortening of one inch confined entirely to the femur. We had gained, therefore, one and one-half inches. He walked much better than when he entered the hospital, had a much less pronounced tilting of the pelvis and the result was in every way satisfactory.

Case 2. *History.*—D. S., a male, aged fourteen, was admitted to the Shriners' Hospital for Crippled Children on March 4, 1925. He had anterior poliomyelitis at the age of seven with the residual paralysis affecting the right lower extremity. The attack was followed by wasting of the muscles of the leg and thigh, but chiefly the leg. He has been treated by massage, exercises and the application of a brace. The chief complaint was that the foot was deformed and that there was a pronounced limp due to shortening.

*Physical Examination.* — Examination showed an atrophy of the muscles of the right lower extremity which was especially marked in the leg. The foot was held in valgus and this deformity was increased when the patient bore weight. All muscles of the thigh were

Fig. 9

Case 1. Photograph eleven months after operation with markings indicating the anterior superior spines of the ilia and the knee joints. The shortening of 2½ inches had been reduced to 1 inch which is confined entirely to the femur.

active and the only muscles which were completely paralyzed were the anterior and posterior tibial muscles, though the gastrocnemius was weak. There was shortening of one and one-half inches which was confined to the tibia.

*Operation.*—March 16, 1925: The pins were inserted through stab incisions in the same manner as has been described above. An incision was then made over the inner aspect of the tendo Achillis and a plastic lengthening was done. The wound was then closed with catgut and silk. A curved incision was then made over the anterolateral aspects of the tibia, the periosteum incised vertically and separated around the bone for a distance of about four and one-half inches. With motor and Gigli saws the tibia was cut in the usual manner. The fibula was sectioned obliquely through the same incision and the wound was closed with catgut and silk. The stabilizers were then attached and

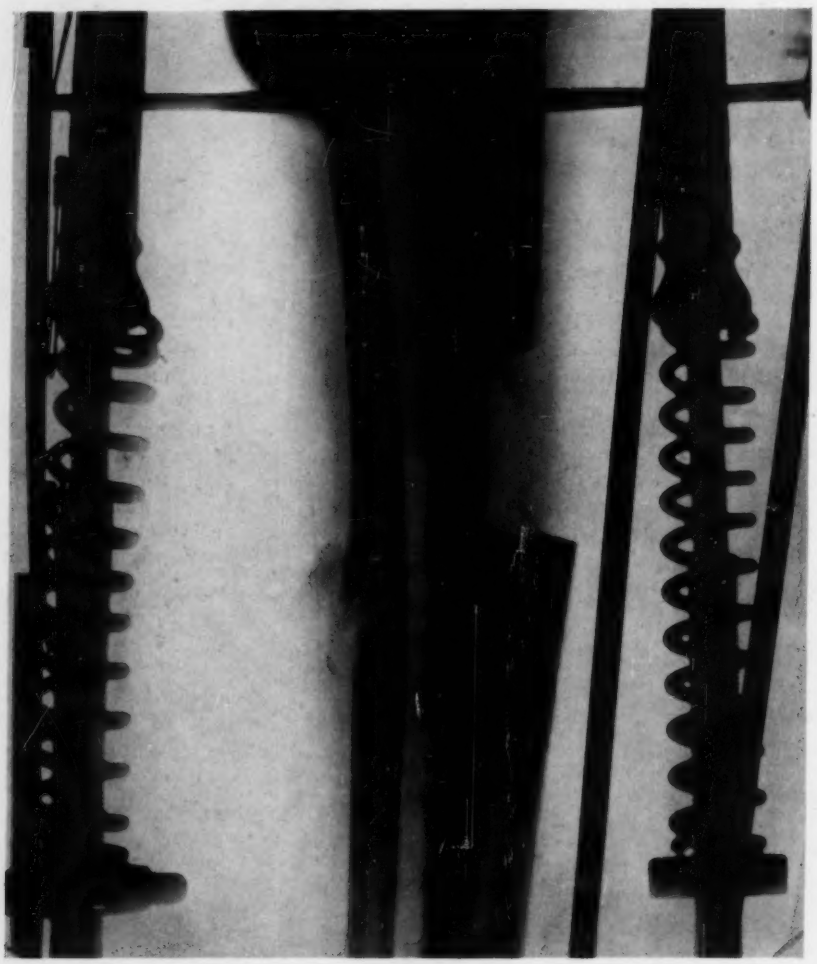


FIG. 10

Case 2. Separation of the fragments of the tibia after twenty-four days of traction. Lengthening of the fibula is not seen because a long, oblique osteotomy was done in an anteroposterior direction and therefore the fragments in the anteroposterior view overlap.

good alignment of the fragments of the tibia was maintained by adjustment of the turnbuckles and the foot support.

*Notes.* March 24.—The swelling has disappeared and the lengthening process was begun by tightening the thumb screws.

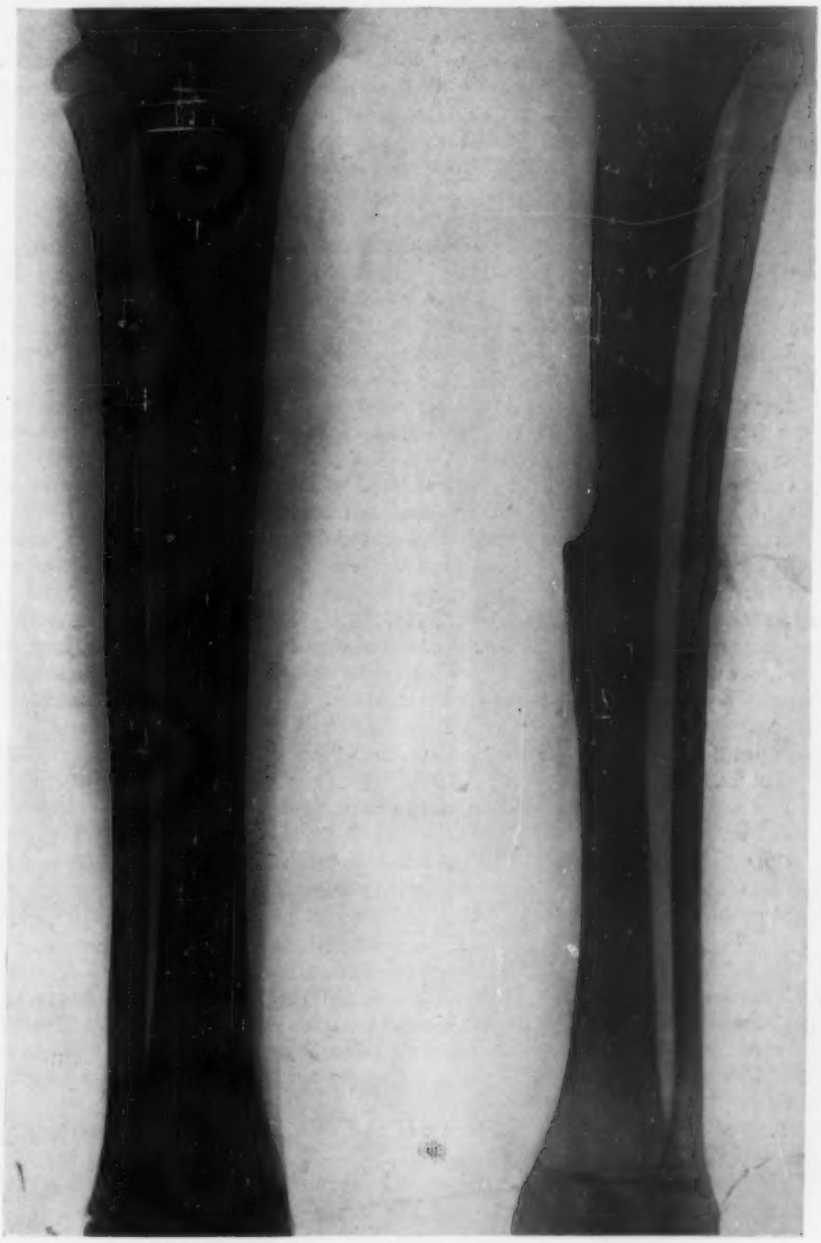


FIG. 11

Case 2. Roentgenogram taken four months after operation, with tibiae on the same plate for comparison, shows them to be of equal length. (Plate has been reversed in printing.)

March 26.—The stitches were removed and the wound was clean.

April 15.—The lengthening process was continued for three weeks and we gained approximately one and one-half inches as shown by measurements.

The roentgenogram, April 17, showed quite a wide separation of the fragments of the tibia, though no separation of the fragments of the fibula could be made out. This was because of the oblique osteotomy done in the anteroposterior direction (Fig. 10).

On May 11, eight weeks after operation, the pins were removed and there was no evidence of infection. Plaster-of-Paris was applied to maintain the fragments in good alignment.

May 20.—The pin wounds were healed.

On June 20, three months after operation, the roentgenograms showed good alignment and considerable callus.

July 11.—Roentgenograms were taken to show a comparison of the length of the tibiae. They measured exactly the same length (Fig. 11). The clinical examination showed firm union.

July 20.—The foot was operated upon by Hoke's method of stabilization and the valgus deformity was corrected.

July 30.—The stitches were removed and the wound was clean. The foot was in good position.

August 25.—The patient was discharged from the hospital wearing a walking caliper brace. The measurements between the anterior superior spines and the internal malleoli were exactly the same.

On September 16, the patient returned to the Outpatient Department, walking without a brace, with solid union and excellent alignment of the tibial fragments. There was no limitation of motion in any of the joints and the foot was stable. The actual gain in the length of the tibia was from one and one-quarter to one and one-half inches.

Case 3. *History.*—H. R., a male, aged fourteen, was admitted to the Shriners' Hospital for Crippled Children on April 6, 1925. His illness began at the age of one and one-half years when he had an attack of anterior poliomyelitis which paralyzed the right lower extremity. He had had practically no treatment, but entered the hospital because of a marked paralysis involving the right leg. He also complained of shortening and a valgus deformity of the foot.

*Physical Examination.*—Examination showed an extensive paralysis involving the right lower extremity, especially the leg. There was a valgus deformity of the foot and two and one-half inches of shortening, one and one-quarter inches of which was confined to the tibia.

*Operation.*—April 15, 1925: The right foot was operated upon by Hoke's method of stabilization. The operation was followed by an uneventful convalescence and the wound healed by first intention.

*Notes.* May 21.—The tendo Achillis was lengthened by a curved incision after the method used by Hoke. The pins were inserted through stab incisions at the upper and lower ends of the shaft of the tibia. A curved incision was made over the anterolateral aspect of the tibia and after incision of the periosteum vertically, a Z-shaped section of the bone was made in the usual manner. A drain was placed at the upper angle of the wound to prevent swelling. The stabilizers and foot-piece were applied and adjusted.

May 23.—The drain was removed and there was practically no swelling of the limb.

On May 27, six days after operation, the lengthening process was begun and the stabilizing apparatus carefully adjusted.

June 1.—The stitches were removed and the wound was clean.

June 21.—The lengthening process had been continued for a little over four weeks and the measurements showed a gain of one and one-half inches. The fragments have remained in good alignment throughout the lengthening process.

July 6.—Roentgenograms showed apposition and excellent alignment of the fragments and a lengthening of about one and one-half inches. There is an error here of at least one-quarter of an inch due to inability to place the film in contact with the posterior aspect of the leg.

July 23.—The pins were removed and the wounds were clean. Fixation was secured by the application of a plaster-of-Paris cast.

August 3.—The pin wounds were healed.

December 4.—The patient was discharged from the hospital wearing a walking caliper brace with coaptation splints. Clinical examination showed solid union of the fragments.

The lengthening of the leg as measured and shown by the roentgenogram was one and one-quarter inches. The foot was stable and in good position. The pelvic tilt was diminished and the gait was very much improved.

CASE 4. *History.*—F. T., a female, aged eleven, was admitted to the Shriners' Hospital for Crippled Children on September 8, 1925. At two and one-half years of age the patient had an attack of anterior poliomyelitis which affected chiefly the right lower extremity. She had had no treatment aside from medical care. Her complaint was that of a difficult gait because of inability to raise herself on the ball of the foot on the affected side. There is also a deformity of the foot.

*Physical Examination.* — Examination showed a calcaneovalgus deformity of the right foot with paralysis of the gastrocnemius and posterior tibial. There was shortening of one and one-half inches.

*Operation.*—September 10, 1925: The pins were placed at the upper and lower parts of the shaft of the tibia and this was followed by the usual Z-shaped osteotomy of the tibia and oblique osteotomy of the fibula. A Thomas splint with stabilizers was fixed in place and the foot-piece adjusted to maintain good alignment of the tibial fragments.

*Notes.* September 14.—There has been a slight rise in temperature and considerable swelling of the leg and foot. There was a severe picric acid reaction with marked erythema of the entire right leg and foot.

September 20.—There has been a very severe reaction of the skin from picric acid which has resulted in the formation of pustules. These have been opened and the skin kept carefully cleansed and a soothing lotion applied. There was considerable pus around the pin wounds. The upper pin was removed for fear that the skin reaction might cause infection of the bone and consequently the idea of lengthening of the leg had to be given

FIG. 12

Case 5. Photograph before operation. A shortening of 2½ inches was present with the amount equally divided between the tibia and femur.

up. Traction was applied, however, to the lower Steinman pin in the hope that we could gain a slight amount of lengthening.

September 24.—The reaction of the skin abated and the swelling went down very considerably.

October 15.—The skin reaction cleared up and the leg looked almost normal. There evidently was no deep infection of the wound and no osteomyelitis. The lower pin was removed and the limb immobilized in a plaster-of-Paris splint. The alignment was good and there seemed to be some union. Roentgenograms were taken to determine if any length had been gained. They showed an actual lengthening of three-quarters of an inch.

January 2, 1926.—All the wounds were healed and there was solid union of the tibial fragments. The shortening had been reduced about one-half, there being a gain of about three-quarters of an inch.

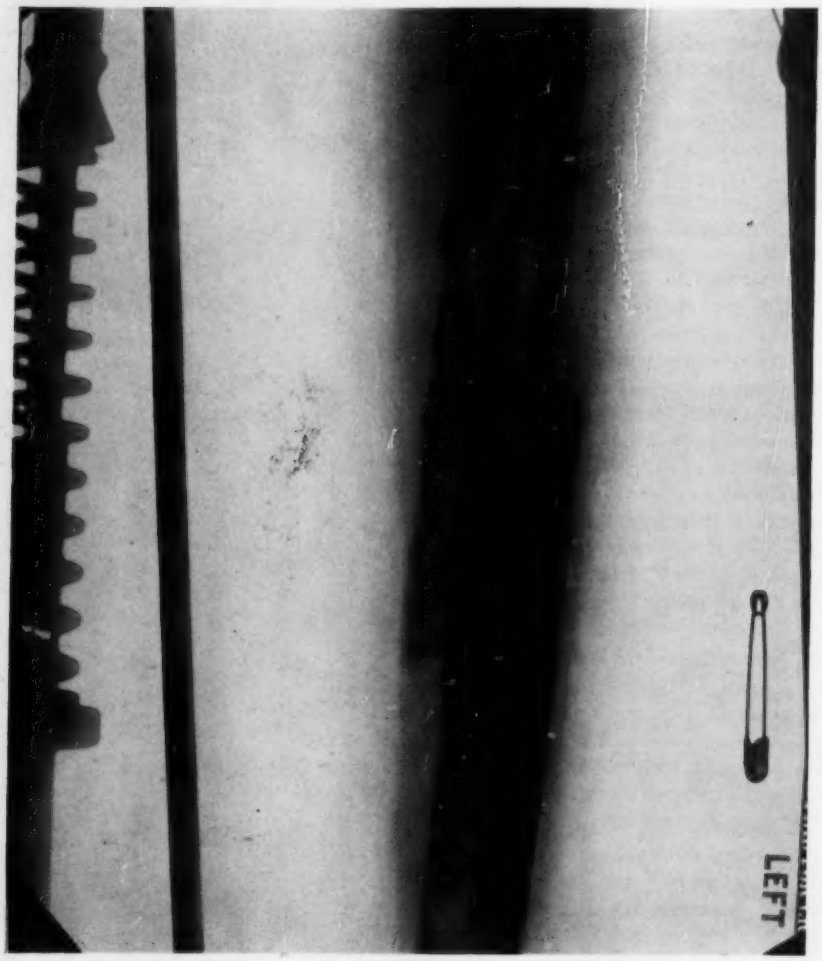



FIG. 13

Case 5. Roentgenogram taken twenty-two days after the beginning of the leg lengthening. The measurement on the film shows a gain of 2¼ inches, but there is an error of ½ inch due to inability to bring the film in contact with the posterior surface of the leg during exposure to the rays.

January 5.—A Hoke operation was done to stabilize the foot.

January 10.—Convalescence from operation was uneventful and the foot was immobilized in a plaster-of-Paris cast.

CASE 5. *History.*—D. T., a male, aged fourteen, was admitted to the Shriners' Hospital for Crippled Children on July 28, 1925. At sixteen months of age the patient had an attack of anterior poliomyelitis which caused a marked paralysis of the left lower extremity. There was great difficulty in walking because of complete paralysis of the quadriceps muscle. There was considerable shortening of the limb and the patient also complained of a deformity of the foot.

*Physical Examination.*—There was a valgus deformity of the left foot and a slight shortening of the tendo Achillis. There was two and one-half inches of shortening of the left lower extremity with the amount equally divided between the femur and the tibia (Fig. 12).

*Notes.* August 3.—The patient's foot was stabilized by the Hoke method.

September 14.—The convalescence from operation has been uneventful and the wound has healed by first intention. There was excellent correction of the deformity and the subastragalar joint was stable.

September 17.—Operation was done with lengthening of the tendo Achillis, insertion of the pins and the usual osteotomies of the tibia and fibula. A drain was inserted in the upper angle of the tibial wound.

September 21.—The drain was removed in forty-eight hours and there has been no marked swelling of the leg.

The lengthening process was begun on September twenty-five and continued up to October 17, a period of twenty-two days. The gain in length as shown by the roentgenogram was two and one-quarter inches (Fig. 13). It is to be remembered here that there is an error of one-half inch because the exposure was not made with the film in contact with the posterior aspect of the leg.

We had felt that in some cases we had lost length when the drill pins were removed due to the fact that sufficient callus had not formed to fix the fragments. It was therefore decided that in this case we would try to secure better fixation by using a bone peg. Consequently on November 23, through a stab incision, a hole was drilled in the two fragments and a small bone peg introduced. The drill pins were then removed and a plaster-of-Paris mould applied to the posterior aspect of the thigh, leg and foot.

FIG. 14

Case 5. Photograph taken four months after lengthening of tibia and fibula. A gain of 1⅞ inches was secured. Compare with photograph taken before operation (Fig. 12).

December 26.—The roentgenogram showed the bone pin holding the fragments in good position. The measurement showed a gain in length of one and three-quarters inches. The roentgenogram also showed the scale with exaggerated markings which is used to secure the true distance between the tibial fragments.

January 10, 1926.—The clinical examination, four months after operation, indicated union of the fragments. The patient was measured for a walking caliper splint. A photograph taken at this time (Fig. 14) showed a gain in length when compared with the photograph taken at the time of admission. The true gain was one and seven-eighths inches.

Case 6. *History.*—H. C., a male, aged twelve, was admitted to the Shriners' Hospital for Crippled Children on September 8, 1925. The onset of his illness was at eight months of age when he had an attack of anterior poliomyelitis followed by paralysis of the left leg.

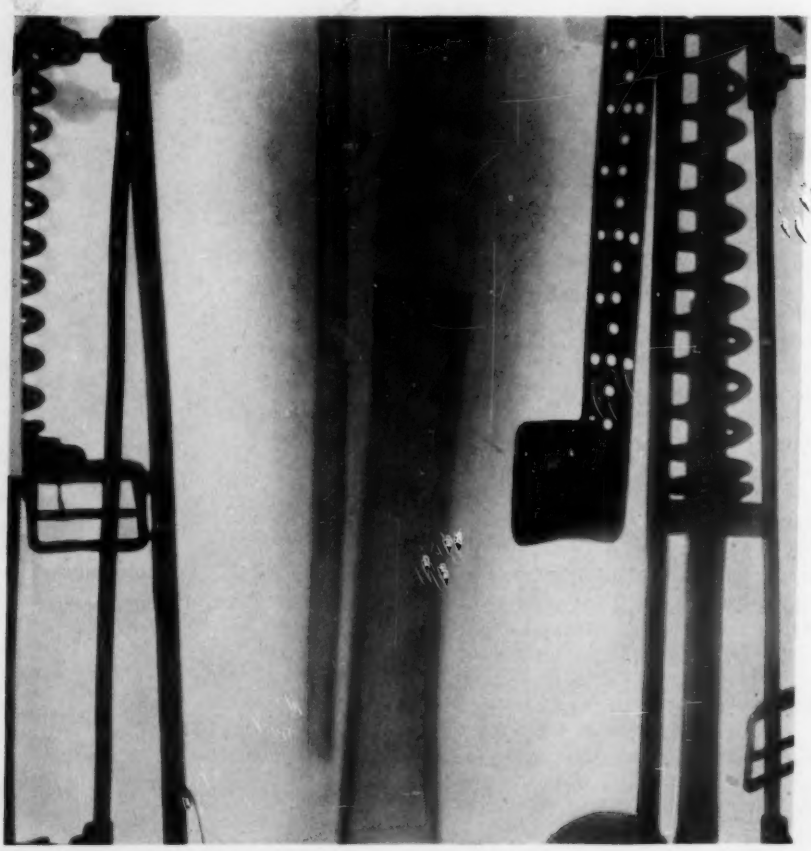


Fig. 15

Case 6. Showing separation of fragments about four weeks after operation and the lead scale which has been placed at the same level as the tibia when the exposure was made. The inch markings on the lead scale are indicated by three dots. The distance separating the fragments as measured by a ruler is 2⅝ inches. When this 2⅝ inches measurement is transferred to the lead scale we get a reading of 1⅞ inches which is the true amount of lengthening obtained.

*Physical Examination.*—Examination showed a very extensive paralysis of the left lower extremity with fair hip muscles, weak quadriceps and a flail foot.

*Notes.* The foot was stabilized by the Hoke method on September 10, 1925. The wound healed by first intention and the convalescence was uneventful.

On November 23, the leg lengthening operation was done by following out the usual steps in the procedure. A drain was placed and removed in forty-eight hours. There was considerable swelling despite the drain.

The leg lengthening process was begun on December 3 and ended December 23, a period of twenty days. The actual gain as shown by measurement was two inches, but the roentgenogram taken with a device to alleviate error showed a lengthening of one and seven-eighths inches (Fig. 15). This discrepancy is accounted for in that there was some bending of the pins during extension, thereby giving an increased measurement over what is actually shown by the roentgenogram.

January 10.—The patient remains in the hospital with the apparatus still in place. The pins are to be removed shortly and the fragments fixed by beef bone screws.

## CONCLUSIONS

1. Lengthening of the tibia and fibula is a procedure which is of great value in cases where the major part of the shortening of a lower extremity is confined to these two bones.

2. The fundamental principles of leg lengthening are the application of traction and countertraction directly to the bone and continued over a considerable period of time. To avoid complications and to promote early union, apposition of the fragments in good alignment is essential. This is best secured by applying traction on both sides of the leg by means of screw extension pieces which are attached to pins passed through the upper and lower ends of the shaft of the tibia. Displacement in an anteroposterior direction is prevented by stabilizers which hold the drill pins in the same horizontal plane.

3. In this operation, because of multiple incisions, penetrating drill pin wounds and the wide opening of the medullary cavity of the tibia, there is considerable danger of infection. This can be minimized by gentle handling of the tissues and by observing the most rigid, aseptic technique throughout the operation.

4. In the six cases treated by this method the lowest gain in length was one and one-quarter inches; the largest one and seven-eighths inches. The results in the completed cases have been highly satisfactory and with the experience which we have acquired we believe that in the average case a gain of two inches should be secured without producing an injury to the blood vessels or nerves.

5. With the operation in its present stage of development, we believe that it should be performed only by those who are adequately equipped to do bone surgery and who by their training have a thorough knowledge of mechanical appliances.

6. It should not become a routine procedure but should be reserved for those who are actually in need of it—those who cannot be relieved by more conservative measures.

## REFERENCES

1. Codivilla, A.: On the Means of Lengthening, in the Lower Limbs, the Muscles and Tissues Which Are Shortened Through Deformity. Am. J. Orthop. Surg., II, 353, April, 1905.
2. Freiberg, A. H.: Codivilla's Method of Lengthening the Lower Extremities. Surg. Gynec. Obst., XIV, 614, 1912.
3. Magnuson, Paul B.: Lengthening Shortened Bones of the Leg by Operation. Univ. Penn. Med. Bull., XXI, 103, May, 1908:
Magnuson, Paul B.: Approximation of the Ends of Fragments in Fractures with Contraction of the Attached Muscles. Ann. Surg., LIV, 227, 1911:
Magnuson, Paul B.: Lengthening Shortened Bones of the Leg by Operation. Surg. Gynec. Obst., XVII, 63, 1913.
4. Ombrédanne.: Allongement d'un femur sur un membre trop court. Bull. et mém. Soc. de Chir. de Paris, XXXIX, 1177, 1913.
5. Taylor, R. T.: Shortening Long Legs and Lengthening Short Legs; A New Surgical Procedure. Am. J. Orth. Surg., XIV, 598, Oct., 1916.
6. Fassett, F. J.: An Inquiry as to Practicability of Equalizing Unequal Legs by Operation. Am. J. Orth. Surg., XVI, 277, Sept., 1918.
7. Putti, V.: The Operative Lengthening of the Femur. J. Am. Med. Assn., LXXVII, 934, Sept. 17, 1921.

# A PHYSIOLOGICAL STUDY OF THE BLOOD SUPPLY OF THE DIAPHYSIS*

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The first systematic studies of the circulation of the blood in bone were carried out by Lexer, and the anatomical findings established by him and his colleagues stand out today as unchallenged and beautifully demonstrated facts. In the article by Lexer, Kuliga and Turk, stereophotographs of x-rays of the various bones injected with mercuroturpentine emulsion give us a visual demonstration of the vascular network of the bones which has not been equalled in any later contributions. The normal anatomy of the blood vessels in bone has, therefore, been established for over twenty years. However, in the course of studying and teaching bone pathology, the anatomical facts of the circulation have not proved an entirely satisfactory basis for the clear understanding of pathological changes.

The controversy about the rôles of the various portions of the bone in the healing of fractures brought into prominence the physiology of bone as distinct from its anatomy. Many other problems of bone pathology have served to emphasize the importance of the physiological point of view in our attempts to fathom bone diseases and to plan a rational therapy for them. One specific example of the beneficent effect of the physiological outlook has been the greatly improved treatment of bone cavities resulting from destructive osteomyelitis. However, in dealing with injuries and diseases of the bone we are confronted with so many and such difficult mechanical problems that, as a general rule, we have paid too little attention to the physiology of the tissues with which we are dealing. Therefore, working from the mechanical side, we have been too content with our anatomical knowledge only and have questioned too little the physiological problems.

Certainly, very little work has been published in English dealing with bone physiologically, with the exception of a considerable literature on the fate of bone grafts. In the foreign literature there is not much additional information to be gained, though Müller's recent book, devoted to the normal and pathological physiology of bone, is most interesting and should stimulate a similar approach in this country. Even in this typically comprehensive work there is, however, very little to be found concerning the circulation of the blood in bone beyond the anatomical facts established by Lexer, and a description of the development of hyperemia at the site of

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fracture or sarcoma. In short, there is practically no exact information about, or even interest in, the physiology of bone and its blood supply, which supply is certainly one of the most vital necessities in repair of injury or combat of disease.

The recent work of Petersen at Johns Hopkins has shown the importance of the proper chemical balance between calcium and phosphorus in the circulating blood to the healing or non-union of fractures. It seemed, therefore, of real value to get some definite idea of the physiology of the vascular network by which the building materials for repair are carried to the fracture, or the defensive troops and war material transported to the trenches in the fight against disease. It appeared probable that some factor other than blood chemistry was responsible for the occurrence of the vast majority of non-unions in a few definite locations. These poor results have long been attributed to vascular factors without, however, any real knowledge of the basic circulatory changes. It, therefore, was in hopes of throwing some light on the physiology of the blood supply in bone that the following experiments were carried out.

Anatomically there are three distinct vascular systems which supply the diaphyses of the long bones. First, the *nutrient artery* piercing the cortex and sending a large branch in the marrow cavity toward each bone end. Second, the *metaphyseal* system of a number of small vessels entering and penetrating the cortex and branching profusely within the marrow of the metaphyseal region. Third, the *periosteal* system encircling the whole surface of the shaft. It was our immediate task to determine the extent of the vascular field of each system and the compensatory anastomotic adaptability of each system to carry on the work of the other two. To do this we employed two methods: (a) injection with India ink along the usual anatomical lines; (b) study of the bone physiology and pathology in connection with the viability of the cells of the cortex and the marrow, and the progress of bone repair in drill holes made in the cortex.

The following is the plan of the experiments. (1) To study the extent of the vascular tree of the *nutrient artery* and the efficiency of its anastomotic twigs; the periosteum was stripped from the shaft and the medullary cavity blocked off with wax plugs at the metaphysis to cut off the metaphyseal vessels. Dogs were sacrificed, injected, and gross and microscopic study of bone defects carried out. The dogs utilized in this way will be considered collectively as Group 1. (2) To study the extent of the *metaphyseal* vessels and their anastomotic ability, the periosteum was stripped up, the nutrient artery ruptured and only the metaphyseal region of the shaft left undisturbed. Dogs were similarly sacrificed, injected and studied. These constitute Group 2. (3) To study the extent of the *periosteal blood supply* and its anastomotic connections, the nutrient artery was ruptured and the medullary canal blocked with wax plugs inserted through a drill hole at each end of the diaphysis. Dogs were similarly sacrificed, injected and studied. These are Group 3.

In each group one dog was sacrificed immediately, one dog in four or

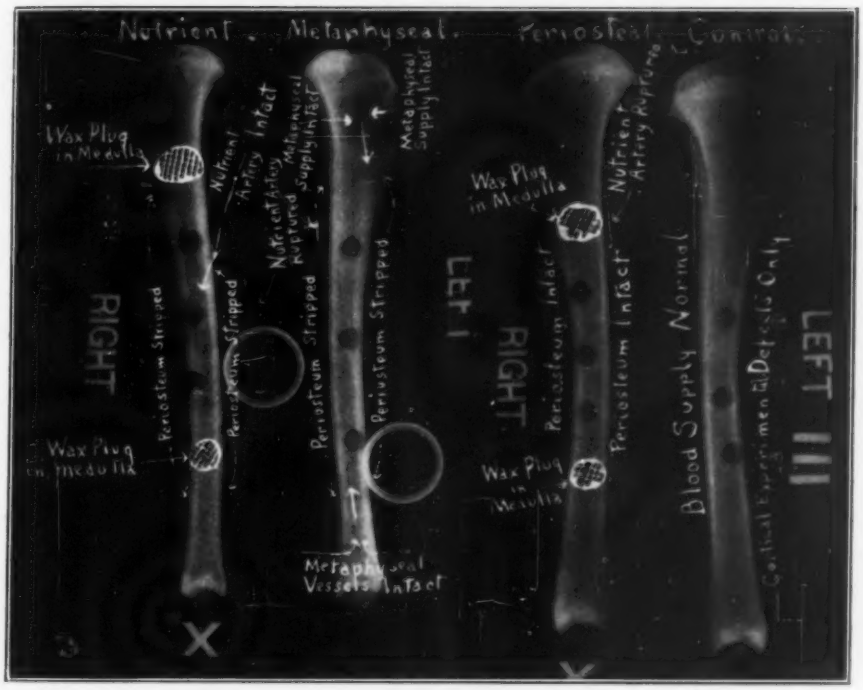


FIG. 1

X-rays illustrating the operative method.

five days, one dog in two weeks, one dog in three weeks, and one dog in four weeks.

Dogs killed immediately were studied together comparatively as Class A; dogs killed in four or five days were similarly treated collectively as Class B; dogs killed in two weeks constitute Class C; dogs killed in three weeks constitute Class D; and dogs killed in four weeks constitute Class E.

| | Group 1<br>Nutrient | Group 2<br>Metaphyseal | Group 3<br>Periosteal |
|---|---|---|---|
| Class A<br>Immediate | Dog 14<br>Right leg | Dog 14, left leg<br>Dog 15, left leg | Dog 15, right leg |
| Class B<br>Four days | Dog 3<br>Right leg | Dog 13<br>Left leg | Dog 2<br>Right leg |
| Class C<br>Two weeks | Dog 9<br>Right leg | Dog 8<br>Right leg | Dog 11<br>Left leg |
| Class D<br>Three weeks | Dog 5<br>Left leg | Dog 10<br>Right leg | Dog 4<br>Left leg |
| Class E<br>Four week | Dog 12<br>Left leg | Dog 6<br>Right leg | Dog 7<br>Right leg |

To avoid confusion let it be emphasized that the term "Group" refers to the differentiation according to the three different blood supplies, and the term "Class" according to the time interval before sacrifice. Each *class* has been studied separately to get a comparison at set time intervals between the extent of the individual vascular systems and their efficiency in promoting repair. Each *group* has been studied separately to get a serial story of the physiological changes taking place following the isolation of the shaft, except for a single vascular supply. Findings in the study of the specimens according to both class and group constitute the general conclusions reached.

Description of the operative technique and the details of the gross, x-ray and microscopic findings in each experimental animal are given at the end of this paper. The summaries of each class and group are as follows:—

## SUMMARY—CLASS A—IMMEDIATE

The results obtained from immediate ink injection showed that a maximum pigmentation of the diaphyseal medulla was obtained when the nutrient artery was alone intact. The metaphyseal vessels and their anastomotic branches gave the second best injection of the medullary portion of the shaft. Injection of the periosteal system, however, was practically ineffectual below the surface of the cortex. The cortical bone in all instances was not discolored to any appreciable degree and no gross injection was to be seen, so that no distinct cortical demarcation could be shown by immediate injection, but this will be demonstrated in the microscopic findings of the later classes.

These findings represent the immediate and fundamental basis from which to start the study of the pathological physiology of the repair process in the later stages of the experiments.

## SUMMARY—CLASS B—FOUR DAYS

1. The absence of adequate injection of the cortex in any section indicated that there is little likelihood of an early effectual anastomosis between medulla and periosteum via the cortical vessels of the shaft.
2. The medullary callus was the earliest and most active factor in the repair of cortical defects.
3. This reparative reaction was particularly active in the case of the undisturbed nutrient artery (Dog 3) which was shown to carry an adequate supply of blood for efficient repair.
4. The metaphyseal supply was successful in maintaining the viability of the marrow unaided, but the repair reaction, especially in mid-shaft defect, was not as active as in the controls.
5. The nutrient artery recovered from trauma and revascularized the medulla rapidly in Dog 2.
6. There was no revascularization of marrow by the periosteal supply through the defects, as each of these was occluded by a complete layer of unorganized blood clot in Dog 3.

7. Cortical necrosis indicated that the outer one-third of the cortex is supplied by the periosteum, while the medullary vessels care for the inner two-thirds, with the nutrient artery being the main factor except close to the metaphyses.

SUMMARY—CLASS C—TWO WEEKS

1. There was poor injection of the cortical vessels in all experiments of this class, showing that anastomosis through the dense bone of the cortex is not to be relied upon as a source of collateral supply even after two weeks.
2. Revascularization and recolonization of the cortex occurred slowly and was not well marked in two weeks.
3. The medullary callus was again the most active agent in repair of defects, though, when only the periosteal supply was left (Dog 11), this response was naturally delayed until revascularization via the defects had taken place and was consequently much less advanced than normal.
4. The metaphyseal and the nutrient blood systems were quite adequate to replace each other and prevent medullary necrosis, while the periosteal supply was hopelessly unequal to doing so.
5. Cortical necrosis zones showed that, roughly speaking, the outer half of the cortex is dependent on the periosteal supply, while the inner half is supplied from the medullary vessels.
6. The periosteum attached slowly and was not active in bridging the defects with bone. Periosteal callus over and in the defects was chiefly fibrous, though when in contact with the surface of the cortex the reaction was osteoid.
7. New bone formed much earlier along the side walls of the defects in contact with the old cortical bone, even though this was necrotic, than in the centre of the defects where it was almost uniformly fibrous and somewhat umbilicated.

SUMMARY—CLASS D—THREE WEEKS

1. The nutrient artery, unaided, was able to supply sufficient blood to allow active and well advanced repair at all defects.
2. The metaphyseal circulation was adequate, alone, to maintain viability of the medulla and inner layers of the cortex and to institute repair, which, however, was not as active or efficient as in the case of the nutrient artery.
3. The periosteal supply did not prevent marrow necrosis when the medullary supply was completely blocked, as shown by 4-X-3 (Fig. 14), but revascularization through the defects did take place and bone repair started, though very much delayed and feeble.
4. The nutrient artery readily resumed function when the foramen and canal were not occluded with wax, even when the extent and degree of periosteal stripping about the foramen showed clearly a rupture of the vessels and severe traumatization of its entrance to the canal.

5. Periosteal repair of large defects was typically umbilicated, its reaction being more and more fibrous in character towards centre of defect.
6. Injection and viability findings indicated that the cortex was supplied from the medulla in its inner two-thirds, and from the periosteum in the outer third.
7. Findings at the end of three weeks differed little from those at two weeks, except that the canals of the cortex had become widened by absorption, and the revascularization and recolonization had progressed markedly in the cortex. The callus in the defects was, of course, more abundant and advanced with denser bone lamellae.

SUMMARY—CLASS E—FOUR WEEKS

1. The intact nutrient artery gave the best injection of the medulla and the most advanced repair of defects.
2. The metaphyseal supply was sufficient to maintain medullary viability, but reparatory activity of the medulla was delayed and depressed.
3. The periosteal supply had served to revitalize the bone via the defects, though there was still some evidence of medullary necrosis.
4. The periosteal new bone was only exuberant where the periosteum had been stripped or traumatized. Where left intact it was thickened but not profusely productive.
5. The cortex showed wider areas of necrosis with more extensive absorption and revascularization at this stage (four weeks) than previously, and there was considerable recolonization of empty lacunae about the enlarged canals.
6. The cortical absorption and revascularization had proceeded so far that a collateral, transcortical supply of some sufficiency had been established at this stage.

*Group 1. Nutrient Artery. Summary of Serial Findings.*

Immediate injection showed in the gross the extent of the nutrient field, i.e., there was complete injection of the marrow cavity between defects No. 1 and No. 3 with ooze of ink from all three holes. The visible injection of the cortex was practically nil.

Starting from this point we found that in four days the periosteum had not yet firmly reattached to the cortex. During this time necrosis of the outer layers of the cortex had taken place and only the inner layers near the medulla were viable. The medulla, itself, was viable throughout. The defects were well filled with medullary callus, which was just as active and extensive in the experimental leg as in the control. Extent of injection was essentially unchanged, showing that there had been no establishment of collateral supply and no increase in the vascular field of the nutrient artery itself.

In two weeks: The periosteum had reattached and was forming new bone over the surface, but as yet very little change in the condition of the

cortex was to be noted. There were no real signs of porosis of the cortical bone, and revascularization and revitalization of the necrotic layers were just beginning. The medullary injection was complete, but practically no cortical injection was visible. Medullary repair was as active as, or more active than in control.

In three weeks: Increasingly abundant periosteal new bone formation had taken place. Porosis of the cortex with process of revascularization and revitalization was much more evident, though not extensive even yet. Medullary injection was very marked and indicated a distinct hyperemia of the medulla with very active callus formation which now filled the whole defect. Medullary injection was more marked than in the control.

In four weeks: There was extreme periosteal new bone formation. The cortex was very porotic at this stage with revitalization actively progressing. Injection of the cortex was well marked. The medulla was also very well injected and repair processes were still very active and, if anything, more efficient than in the controls.

*Group 2. Metaphyseal Vessels. Summary of Serial Findings.*

The immediate injection of Dog 15 showed distribution of the ink throughout the whole medulla when only the metaphyseal vessels were intact. In the animals allowed to go longer the injection and cellular viability of the medullary tissues demonstrated a collateral circulation within the medulla, which is both immediate and efficient in maintaining normal nutrition. The reparative processes in defects No. 1 and No. 3 of this group seemed to be somewhat slowed down, though this was not a constant finding, while the delay at defect No. 2 was distinctly more marked. While the injection of the medulla in all cases was complete there was evidently a delay in the hyperemia which restricted the proliferation of the medullary callus, the restriction and delay being greatest at defect No. 2 which was farthest from the metaphyses. The presence of defects No. 1and No. 3 probably accentuated this delay by unavoidable trauma to the medulla at operation, and by subsequent partial plugging of the canal by callus at these two points. However, on the whole, one was struck by the efficiency of the collateral circulation and the rapidity and extent of the medullary repair.

The cortex retained viability, as a rule, in its inner one-third, but the cortical revascularization was slower than was the case in Group 1.

All these findings showed an appreciable depression in the response of the medullary tissues of the diaphysis depending solely on the metaphyseal collateral supply as compared to Group 1, or the controls.

*Group 3. Periosteal System. Summary of Serial Findings.*

In the immediate injection the lack of any ink in the medullary canal showed that there was insufficient collateral anastomosis through the cortex to allow ink to penetrate. This was also borne out by the findings at

operation on the other dogs of this group. In each instance there was no bleeding from the defects after the nutrient and metaphyseal supplies had been cut off.

The microscopic and the injection findings in the dogs which were saved over varying periods were not so definite and clear cut as had been hoped. This was largely due to the technical difficulty of making certain of the avulsion of the nutrient artery from the foramen and the permanent blocking of the foramen with wax. Owing to its position on the outer posterior aspect of the tibia it was not possible to clearly expose the vessel and dissection had largely to be done blindly. In each case the foramen was identified by the tip of the elevator, and a rough scraping of soft tissues from the bone was done for a considerable area about this point. While the periosteal thickening always found, postmortem, about the entrance of the foramen showed that the periosteum had been roughly stripped and the vessel torn, the foramen itself was only once found plugged with wax, and then only partially, so that a rapid reestablishment of a severely traumatized or even torn nutrient artery was not definitely preventable. This reestablishment certainly did occur, as shown by the injection tests. However, in spite of it we can gather from the evidence of injection and microscopic sections the following facts.

There was no immediate collateral supply to the medulla from the periosteum via the cortical vessels. The nutrient artery soon became reestablished even in the face of a great deal of local trauma (outside the nutrient canal). The outer one-half or less of the cortex only was kept supplied via the periosteum. When the nutrient and metaphyseal supply was completely cut off there was medullary necrosis, as shown in 4-X-3 (Fig. 14).

The medullary callus was much delayed in most instances. The revascularization of the medulla via a defect did not begin to take place until after five days at least, but later on this was a big factor in the formation of the callus in the bottom of the defects.

### *Observations of a General Character Made During the Course of the Experiment.*

Traumatization in the form of rough stripping up, stimulated the periosteum markedly to new bone formation. Periosteal new bone formation, however, was well and quickly produced only when the new bone was laid down upon a foundation of old bone. Periosteum did not bridge a dead space, such as a defect, well and the reaction here was largely fibrous and only became osseous close to the side walls or at the base where there was a contact against old bone. The centre of the defect, which relied on periosteal repair, was always umbilicated. The medullary callus was the most rapidly formed and prolific agent in the early repair of cortical defects, and welled up rapidly from the bottom to fill the dead space. Medullary callus did not seem to pass through a cartilaginous stage but ossification

proceeded directly from conversion of fibrous type of callus. Periosteal callus was often seen to be cartilaginous.

Bone wax could not be made to adhere to the cortical surface, but when rubbed in as evenly as possible was found at autopsy to be collected into small masses and surrounded with dense fibrous tissue, acting as an irritant which increased periosteal reaction and new bone formation. The bone wax plugs which were placed in the central canal always seemed to cause an exuberant periosteal new bone formation on the surface which gave rise to an external fusiform enlargement at these points.

The use of fine silver wire as a subcuticular skin suture was a great technical improvement over the ordinary silk closure. The legs were very greatly and extensively traumatized by the operative procedure necessary, and in all cases the silver wire held despite considerable tension and swelling and was a great help in preventing postoperative wound infection in these animals.

The following diagrams express as graphically as possible our conclusions, both as to the extent of the immediate collateral anastomotic powers of each of the three vascular systems of the diaphysis, as shown by injection and cellular viability, and as to the influence that each system has upon the progress of bone repair. This repair is our best index of the physiological status of the bone existing in the various regions of the diaphysis. The diagrams indicate the extent to which each separate vascular system is able to maintain the viability of the cells in various regions of the diaphysis, as shown by the presence of shading. The density of the shading indicates the degree of physiological activity of the cells as tested by their ability to produce bone repair.

## CONCLUSIONS

To express our conclusions verbally as well as diagrammatically, the following statements are made.

1. The nutrient vessels maintain viability throughout the medulla and supply the inner half of the cortex. Repair is active when the nutrient vessels alone are intact.

2. The metaphyseal vessels maintain viability throughout the medulla and the inner half of the cortex, but repair is not as active as in the controls except close to the metaphyseal ends, being notably delayed in the middle region of the shaft.

3. The periosteal system does not normally supply more than the outer half of the cortex and is unable to afford an effectual collateral supply to the medulla of the diaphysis under four weeks' time. The periosteal repair is relatively poor in the healing of cortical defects.

4. Regarding the shaft as a whole, the nutrient vessels are the most important, the metaphyseals next, and the periosteal system the least.

5. In all conditions affecting the diaphysis, the blood supply is a most vital factor, and with the above experimental, anatomical, and

physiological data clearly established we are in a better position to rationally study and deal with such problems as non-union, delayed union, massive bone transplants, acute osteomyelitis, and kindred diseases.

## OPERATIVE TECHNIQUE AND DETAILS OF EXPERIMENTAL FINDINGS

In each dog one tibia was used as the experimental bone, operated upon and treated according to the technique given below. The opposite tibia was used in each case as a control. In the following description of findings the first numeral indicates the number of the dog, the letter X indicates that the specimen is from the experimental leg while C indicates the control leg. The final number, 1, 2 or 3, indicates the position of the bone defect—1 being the proximal hole; 2, the middle hole (usually about the centre of the shaft), 3, the distal hole. The holes made for insertion of wax plugs are ignored. Large dogs were selected in order to make definition of bone regions, etc., easier, and in all cases, except one, the dogs were quite old so that normal repair would not be extremely rapid.

The following operative technique was used:—

Both legs were shaved from mid-thigh to below the ankle joint. The leg having the best skin surface after shaving was selected for the experimental procedure and the other leg used as a control. Ether anaesthesia was used; iodine clean up; both legs were draped with towels sewn to the skin over the tibia to minimize contamination. Skin incision was made over the anteromesial surface of the tibia and the shaft of the bone widely exposed.

From this point three different procedures were used, description of which follows:

Technique 1. Isolation of the shaft from all blood supply, except that of the *Nutrient Artery*. The periosteum was first incised anteriorly and stripped with a sharp periosteal elevator over the whole medial and external surfaces of the diaphysis. The lower one-half of the posterior surface was also stripped and the medial portion of the upper posterior surface freed gently. The upper, outer posterior surface of the shaft was left undisturbed, as it is here that the nutrient artery perforates the periosteum to enter the nutrient foramen. After this stripping of the periosteum, bone wax was rubbed into the surface of the cortex as thoroughly as possible to occlude any small periosteal foramina containing small vessels. A drill hole was then made in the bone at each end, at about the junction of the diaphysis and the metaphysis. Then the central canal was cleaned out with a sharp curette and the holes plugged tightly with bone wax to completely occlude the whole medullary canal at these two points, thus blocking off all collateral supply of the diaphysis from the metaphyseal vessels. This technique temporarily left only the nutrient artery intact to supply the whole diaphysis until a collateral supply could be reestablished. With a six millimeter drill three defects were made in the cortex of the shaft, care being taken to have each defect include only the cortex down to the medulla in order to expose the endosteal bone and yet traumatize and break down the medullary structures as little as possible.

Technique 2. *Metaphyseal Vessels.* Isolation of the shaft from all blood supply but that of metaphyseal vessels. The periosteum was entirely stripped from the whole diaphysis by sharp periosteal elevator, and in this process the nutrient artery was also ruptured at its entrance into the foramen. A gauze sponge was then passed around and under the bone and a large flat piece of bone wax thoroughly worked into the cortical porosities, and especially into the nutrient foramen, by pulling gauze up and down and back and forth behind and around the shaft. The medulla was not disturbed in any way except that the three cortical defects were made, as before described, to test repair processes. There was no interference with the medullary ramifications of the metaphyseal vessels or the intracortical part of the nutrient vessels. The periosteum

over the metaphysis was not stripped up and the entrance of the metaphyseal supply thus was undisturbed.

Technique 3. *Periosteal System.* Here the shaft was left with a blood supply limited to the periosteal system. Since the periosteum was to be left intact there was considerably more difficulty, because, in order to reach and rupture the nutrient vessels and block the foramen, some of the periosteum in the upper postero-external aspect of the diaphysis had to be traumatized and stripped up. It was impossible to see the vessels, so a fairly large area in this region had to be stripped to insure the temporary elimination of the nutrient supply. Also, the anterior periosteum had to be incised in five places in order to expose the cortex for drilling of five holes—two for the insertion of wax plugs to block off the metaphyseal vessels at each end and three to serve as experimental defects in the diaphyseal portion. Except for this necessary trauma the periosteum was left undisturbed.

In all cases the soft tissues, including the incisions in the periosteum, were sutured with fine black silk but the skin itself was closed with a subcuticular continuous silver wire suture, except in dogs 2, 3, 4 and 5, where only silk was used.

Following the closure of the wound on the experimental leg, three small incisions were made over the tibia of the opposite leg and the cortex exposed. A control cortical defect was made through each incision to correspond to the defects on the experimental side. In the drilling of the defects care was taken to remove all bone chips as far as possible and the defect was left as a dead space filled with blood.

In dogs 2, 3, 4, 5 and 6, a plaster cast was applied to the experimental leg to hold dressings in place but this was soon found to be unnecessary and a simple collodion gauze dressing was applied instead, after the ends of the silver wire had been cut off flush with the skin.

All cases healed without infection, although in dog 2 the swelling was so great that the silk skin sutures cut out and the wound opened superficially so that the dog was sacrificed sooner than originally planned and placed in an earlier class for study.

The dogs were kept under usual kennel conditions and sacrificed by exsanguination under ether anaesthesia. After death the iliac vessels, or the aorta, were exposed and the vascular trees of both legs thoroughly washed with salt solution, following which an India ink solution (one part ink to two of salt solution) was injected with a large syringe under hand controlled pressure until the extremities showed complete soft tissue injection. Both tibiae were then removed, sawed sagittally with a fine coping saw to expose medulla for gross study and to allow good fixation of the tissue in formalin for later cellular study. Gross examinations of the bone and x-rays were made.

Finally, a block of each defect was made and prepared for microscopic study. Sections were cut so as to give a sagittal section of the central area of the defect and the contiguous cortex and medulla. In most cases the fibrous periosteum was practically completely stripped from the bone in order to allow gross observation of the bone surface so as to observe the degree of injection. Therefore, the fibrous periosteum is absent in some microscopic slides.

## REPORT OF EXPERIMENTS AND FINDINGS

### Class A

*Group 1.* Nutrient Artery.

Dog 14. Operated on right leg on June 2, 1925 according to technique No. 1 above described. Dog immediately killed and injected.

*Gross Findings:*—On injection all three drill holes in the shaft oozed ink profusely. Nutrient vessel was, therefore, intact and functioning sufficiently to distribute ink to all three defects. Examination of bone after removal showed good injection of both ends with discoloration of the surface. The surface of the diaphyseal cortex was not discolored with ink. On sawing the bone open the two ends as far as the wax plugs were densely injected. The central portion of the medulla between the first and second defects was completely injected. There was some injection of the marrow between

defects No. 2 and No. 3. There was very slight injection of the cortex from the nutrient artery.

CLASS A

*Group 2.* Metaphyseal Vessels.

Dog 14. Operated on left leg on June 2, 1925 according to technique No. 2. Dog killed and injected immediately after operation.

*Gross Findings:*—During injection there was oozing of inky fluid from both the upper and lower defects, but very little from the lower and none from the middle defect. There was no discoloration of the surface of the cortex. On splitting the bone there was found complete injection of the upper third of the medulla, down to the first drill hole where it stopped abruptly. Although care had been taken to injure the medulla as little as possible in drilling, yet there were bloody effusions in the marrow below each of the defects and no signs of injection between the first and third defects. The whole lower end of the bone was so poorly injected that the experiment was repeated the next day on the left leg of Dog 15.

CLASS A

*Group 2.* Metaphyseal Vessels.

Dog 15. Left leg operated on June 3, 1925 by technique No. 2, except that, instead of three defects, only one was made in the middle portion of the shaft. Dog killed and injected immediately.

*Gross Findings:*—Good injection obtained. There was slight oozing of ink from defect in mid-portion of the shaft. There was no staining of the surface of cortex except at each end, where periosteum was left undisturbed over the metaphyses. Moderately dense injection of the upper and lower end of bone and visible injection of the small vessels of the marrow running towards the defect from both the upper and lower metaphyses. No discoloration or injection of cortex seen in the region stripped of periosteum. The nutrient artery completely ruptured and not injected.

This specimen was far more satisfactory than Dog 14, and showed the immediate collateral circulatory extent of the metaphyseal supply. The injected ink seemed to reach the entire medullary cavity via the metaphyseal vessels, but the cortex was not injected.

CLASS A

*Group 3.* Periosteal System.

Dog 15. Right leg operated upon on June 3, 1925 by technique No. 3 with, however, only one test defect in the mid-shaft. Killed and injected immediately.

*Gross Findings:*—No ink to be seen in the nutrient canal. Surface of the bone slightly discolored with ink, more posteriorly than elsewhere. The bone, on sawing, showed practically complete absence of ink from the central canal. Near the upper third of the shaft was a very fine group of vessels in the medulla which were injected and apparently had their origin from the periosteal network as they were almost immediately lost in the cortical bone. Very slight injection of the cortical bone elsewhere.

CLASS A

*Controls:*—

Dog 1. In right leg the shaft of the tibia was completely isolated by rupturing nutrient artery, plugging the medulla at the metaphysis and completely stripping the periosteum. Injection of this bone confirmed the practicability of complete isolation of the shaft by this means as there was no ink to be seen in the shaft, though the undisturbed bone ends were well injected.

Left leg not operated upon but immediately injected after death and showed complete injection of both bone ends and of the shaft itself, both within the medulla and over the surface. The cortex was poorly injected, even in this specimen.

Dog 15. Both femora which had been undisturbed by any operative procedure were removed after the injection for study and comparison.

*Gross Findings:*—Complete injection of both femora with maximum pigmentation

at the epiphyseal ends, though the medulla of the shaft stood out clearly injected too. Only slight injection of some of the small vessels of the cortical bone but the periosteal network very profusely injected. The periosteal network composed of finer vessels than the medullary vessels. Both bones equally injected.

CLASS B

*Group 1.* Nutrient Artery. Four days' duration.

Dog 3. Right leg operated on by technique No. 1 on April 25, 1925. Sacrificed April 29.

*Gross Findings:*—Periosteum much thicker on the experimental leg than on control. On sawing bones, cortex found not to be injected appreciably, even in the control. Both ends of the experimental bone completely injected. Wax plugs completely blocked each end of shaft medulla and cut off the metaphyseal supply entirely. Nutrient artery well injected but an obstruction to it observed at the second defect, interfering very much with circulation below hole No. 2. On the control side the bone showed normal, uniform injection. Measurements of the external and internal callus at each defect were made on both bones but gave no definite information which was not more clearly shown by microscopic findings later on, so these are omitted. X-rays were taken both anteroposteriorly, to show defects in profile, and laterally to get a through-and-through view of them. These showed no appreciable difference in the shadows cast by the experimental defects in the two bones.

*Microscopic Notes:*—

*3-X-1.* No periosteal reaction. Surface of cortex covered with blood clot. Cortex showed no injection except at one or two points close to medullary surface. Cells of cortex shrunken and broken up except in deepest layers. Cells in cortical canals also necrotic in outer half of cortex. Marked injection with very active proliferation in the medullary region, cells being mostly undifferentiated in type as yet, though some osteoid tissue was seen. Defect filled to one-quarter of its depth with unorganized blood clot which extended clear across the whole defect. This clot was being invaded by very vascular and actively proliferating tissue from the medullary side, and this tissue filled the bottom three-fourths of hole and was actively repairing the defect.

*3-C-1.* Some periosteal reaction with thickened and injected periosteum closely attached to the bone. Cortical cell death seen only close to edge of defect. Fair injection of cortical vessels. Medulla well injected. In the defect there was a large mass of blood clot which was beginning to show organization from medullary side but no

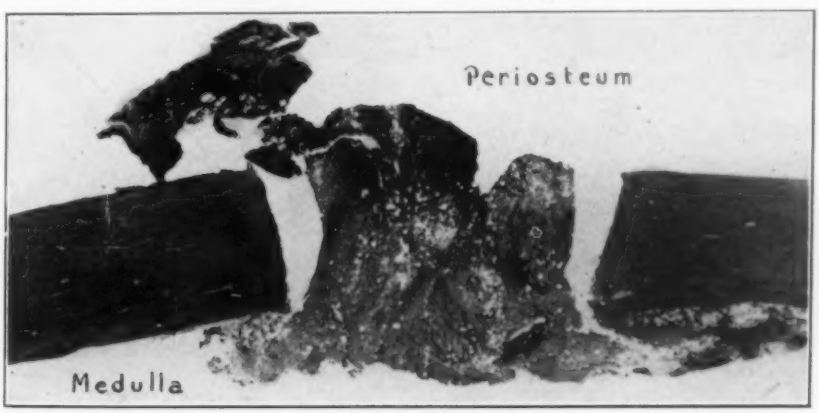


FIG. 2. 3-X-1

Group 1, Class B.—Nutrient Vessels. Four days' duration.
No periosteal reaction. Cortex very poorly injected. Defect being repaired only from medullary side, where activity is very marked.

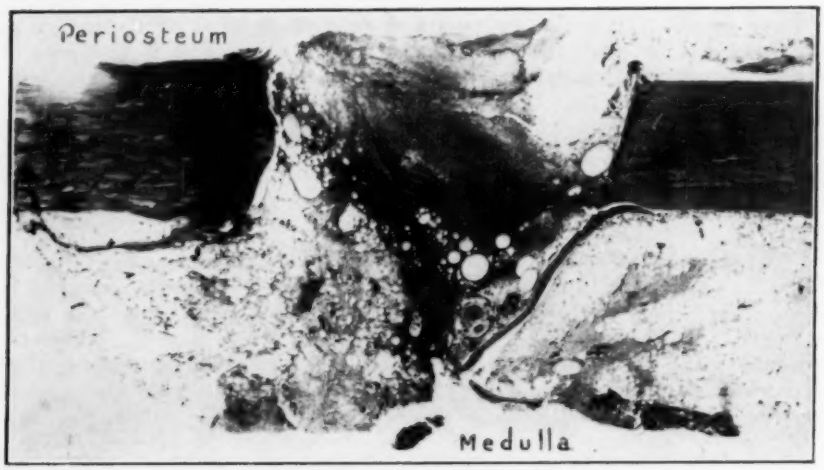


FIG. 3. 3-C-1

(Control for 3-X-1.) Early periosteal reaction and beginning repair. Fair cortical injection. Medullary response rather less active than 3-X-1.

active down-growth of tissue from periosteal side. The organization had not proceeded as rapidly as in 3-X-1.

*3-X-2.* Periosteum had not reattached. Cortex on upper side of defect fairly well injected except in outer third. Bone cells necrotic close to defect and along outer layers of cortex. More cells viable in medullary half of cortex, though even here there were islands of necrosis. The cortex, distal to defect, entirely uninjected and necrotic. A little medullary callus formation on proximal side of defect but none distally, and the defect was practically filled with unorganized blood clot. Tissue was fragile and was damaged in preparation.

*3-C-2.* Moderate periosteal thickening over the surface of cortex but no periosteal callus shown over the defect itself. Cortex fairly well injected and cells generally viable except close to defect. Medulla well injected and there was a tide of organization sweeping into the defect from the medullary side, carrying with it many injected vessels. This filled bottom two-thirds of the defect while the outer one-third was filled with unorganized clot. No cortical callus.

*3-X-3.* No injection at all. Complete necrosis of medulla and cortex. Defect filled with blood clot showing no trace of organization.

*3-C-3.* Similar to 3-C-2.

Summary of findings in Experiment, Dog 3.

Periosteum did not reattach and reestablish circulatory communication with cortex within four days, during which time necrosis of the bone cells in the outer layers of the cortex occurred.

Medullary circulation was not sufficient to supply entirely the cortical bone so that, roughly speaking, the outer half of the cortex became necrotic when the periosteum was stripped, even if nutrient vessels were left intact.

Drilling through the bone caused cortical necrosis by trauma in the region bordering defect.

Making the cortical defect with drill may so injure the medulla that through and through circulation may be temporarily interrupted. In making hole at 3-X-2 the nutrient branches were so damaged that all circulation was cut off distal to it and complete necrosis of the shaft between defects 2 and 3 was caused.

The medullary callus found when the nutrient artery was intact showed itself a very efficient agent in organizing in four days' time the blood clot filling defect.

The callus, organization and injection at defect 3-X-1 were no less than those found at any of the control defects.

CLASS B

*Group 2.* Metaphyseal, four days' duration.

Dog 13. Left leg operated on by technique 2 on June 4, 1925. Sacrificed and injected June 8.

*Gross Findings:*—Experimental tibia. There was a little roughening of the bone posteriorly and at edges where periosteal stripping stopped. The nutrient canal was seen to be filled with wax. There was no injection of the nutrient artery in the foramen. The bone wax which had been rubbed into the surface of the bone was found gathered together in small particles and lumps surrounded by dense fibrous tissue. The periosteum had become lightly reattached to the bone despite the bone wax treatment of the surface. The bone, when split, showed a fair injection at the ends and a remarkable network of thickened vessels extending from the metaphyses up and down toward the middle of the shaft. The intramedullary branches of the nutrient artery had been injected by collaterals from the metaphyseal supply. The cortex was not visibly injected. The medulla was fatty, but there was a moderate amount of medullary callus about the three defects.

*Right leg—Control:*—Some external callus, no periosteal thickening. Nutrient artery injected. Both bones were well injected and, apparently, had a good internal blood supply.

*X-rays:*—No definite difference in density of callus formation in the two bones.

*Microscopic Notes:*—

*13-X-1.* Periosteum had not effectively reattached to cortex. Cortex showed cell death superficially and some varying degeneration of cells in its middle region. Deeper layers viable except quite close to defect. Ink visible in some of the deeper cortical vessels and outward, as far as middle, but there was no injection seen in outer layers. Defect filled chiefly with fibrinous clot but some organization beginning from medullary side. There was quite pronounced early medullary callus, which was well injected both above and below the defect.

*13-C-1.* Cortex showed no necrosis except very close to defect, though there was no injection of cortical vessels. Defect filled with clot which was being organized from medullary side. Injection and reparative activity about equal in 13-X-1 and 13-C-1.

*13-X-2.* Essentially similar to 13-X-1, but repair was less active and proliferation of cells less marked. Injection of medullary vessels good. Cortex not injected.

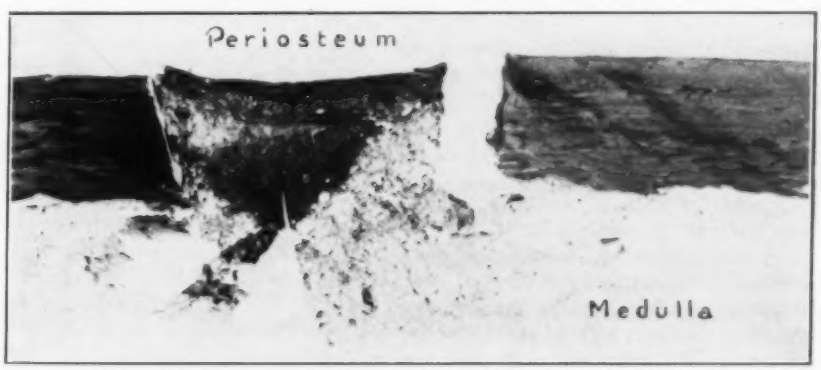


FIG. 4. 13-X-1

Group 2, Class B.—Metaphyseal. Four days' duration.
Periosteum not reattached to cortex. Cortical necrosis superficially. Cortical injection very poor. Defect filled with fibrinous clot which is beginning to show a little organization from medulla.

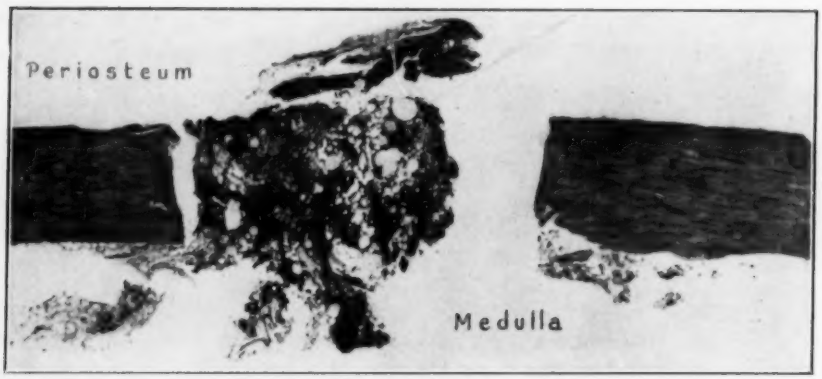


FIG. 5. 13-C-1

(Control to 13-X-1.) Periosteum not reattached. No cortical necrosis. Cortical injection very poor. Defect shows beginning organization, similar to 13-X-1.

*13-C-2.* Not notably different from 13-X-2.

*13-X-3.* Very moderate superficial cell death in cortex. Rest of cortex viable though not well injected. Marked vascularity in medulla, and medullary callus well formed and progressing rapidly.

*13-C-3.* Less ink injection visible and callus formation does not seem as far advanced or as active as in 13-X-3.

*Summary, Dog 13.* Good injection of medulla with an enlarged network of collateral vessels. Superficial cortical necrosis. Cortex not injected. Periosteum not taking part in the repair of the defect. Medullary response as active and injection as good as in control. Activity at middle defect much less marked than at the two nearer the metaphyses, but entire medulla seemed to be supplied from metaphyseal vessels sufficiently well to prevent any medullary necrosis and to enable central repair to proceed at a practically normal rate.

CLASS B

*Group 3.* Periosteal. Duration four days.

*Dog 2.* Right leg operated upon by technique 3 on April 22, 1925. Sacrificed and injected five days later.

*Gross Findings:*—On stripping periosteum there was very little discoloration of the surface of shaft. Nutrient artery was present in the foramen but showed no gross injection. Bone about nutrient foramen was roughened where periosteum had been scraped up. Bone when split showed fair injection of both ends but poor injection of shaft medulla. There were small vessels injected in the medulla, in region of the defects. Internal callus well marked. Control bone showed fair injection throughout.

*X-ray:*—The shadows about defects in experimental bone seemed slightly denser than in control.

*Microscopic Notes:*—

*2-X-1.* Periosteum thickened about defect and actively proliferating new bone. Surface organization extended over defect. Cortex showed viable cells throughout except bordering defect. No injection of small cortical vessels. The defect was filled with a layer of blood clot extending completely across it, which was being organized from the periosteum above and the medulla below. A great deal of medullary callus formed. Poor ink injection of vessels of medullary callus. No necrosis seen in medullary area.

*2-C-1.* Practically similar findings as described for 2-X-1.

*2-X-2.* Similar to 2-X-1. Marked periosteal activity. Cortical cells viable. No injection of cortical vessels. Blood clot layer extended across defect, between periosteal and medullary callus. Marked medullary activity with some slight injection of vessels. Medullary cells viable, both above and below defect.

*2-C-2.* Control is similar to 2-X-2.

*2-X-3.* Marked periosteal activity. Cortical cells viable, except in deeper layers on distal side of defect. There was also necrosis of marrow tissue below defect, between it and the distal wax plug. Medullary callus forming but not as extensive or active as in 2-C-3, 2-X-2 or 2-X-1. No injection of medullary vessels seen. Unorganized layer extended across defect.

*2-C-3.* Similar to 2-C-1 and 2-C-2. No necrosis seen anywhere.

*Summary, Dog 2.* We do not feel that in this animal we were successful in more than temporarily shutting off the nutrient supply, although there was no ink to be seen in the extracortical portion of nutrient vessel following injection, nor was there bleeding from the defects at the time of the operation. The layer of unorganized blood clot in each defect precluded the early vascularization of the marrow cavity through the defects. The lack of injection of the cortical vessels made efficient anastomotic circulation through the cortex most improbable. Therefore, we must conclude that the nutrient vessel was only temporarily damaged and not avulsed, so that this source of supply was reestablished too quickly to allow us to consider this experiment entirely satisfactory. It was made clear, however, that revascularization via the defects had not occurred in five days' time, and that the cortical anastomosis was not effectual both because of the lack of cortical injection everywhere and the presence of marrow necrosis in the isolated area between defect X-3 and the distal wax plug.

### Class C

*Group 1.* Nutrient Artery. Duration, two weeks and two days.

*Dog 9.* Right leg. Operated upon by technique 1 on May 17, 1925. Wounds healed and dog was in good condition until May 28 when he got distemper. Died of distemper, June 1. Autopsied and injected June 2.

*Gross Findings:*—Good injection was obtained of both experimental and control bones. Greater periosteal reaction about shaft of experimental bone, where periosteum had been stripped, than about control. In experimental bone, nutrient artery well injected and medullary canal also well injected via nutrient as far as wax plugs at either end. Cortex in both bones only slightly injected. Considerable hard callus at each defect. External callus rather poor but certainly as well marked on the experimental side as on the control.

*X-ray:* Slightly more density of callus on experimental bone than on control.

*Microscopic Notes:*—

*9-X-1.* Periosteum had reattached to bone surface but its reaction was entirely fibrous. Cortex showed very little injection of fine canals with ink. Bone cells in outer half of cortex were almost all necrotic, only occasional islands of cells which stained, and these were close to larger canals. Majority of cells in inner half of cortex stained well, though here there were some islands of necrosis as well. Canals near surface frequently filled with broken down cells, though in places revitalization was occurring. Inner portion of cortex showed proliferation of soft tissues and increase in calibre of canals. Defect was filled with fibrous tissue and new bone. Osteogenesis limited to bottom of defect and along edges in close apposition to old cortical bone. Repair reaction and injection much more marked at one end of defect than at other. Several large vessels were injected, showing that this was probably central end of section from which direction branches of nutrient vessel were coming. However, metaphyseal end of section also showed moderate injection and fair repair activity. Outer part of callus plug filling defect, the result of periosteal reformation was vascular but densely fibrous and showed no osteogenesis. No medullary necrosis.

*9-C-1.* Moderate periosteal new bone formation. Cortical cells viable, except very close to edge of defect. Poor injection of cortical vessels but more marked than 9-X-1. Medullary callus about same in character and amount as 9-X-1. Medullary injection equal to 9-X-1.

*9-X-2.* No periosteal callus in section. Cortical cells not stained in outer half.

Viable and stained well along inner layers. Poor injection of cortical vessels. Bottom and sides of defect filled with osteogenetic cells but all new bone seemed to spring from medulla and surface of defect was covered with fibrous tissue only. No medullary necrosis. Good central injection.

*9-C-2.* Moderate periosteal reaction. Cortical cells viable throughout. Fair injection of cortex from surface and from medulla. Good injection, medulla. Callus in defect fibrous on surface and osteoid along sides and at bottom.

*9-X-3.* Almost exactly similar to 9-X-2.

*9-C-3.* Almost exactly similar to 9-C-2.

*Summary, Dog 9.* Roughly speaking, cell death occurred in the outer half of cortex of the experimental bone while viability was good in the control. Periosteal callus showed little activity and practically no osteogenetic power in either experimental or control bone. Medullary reaction was marked and activity osteogenetic and about equal in all defects, experimental as well as control. There was poor injection of the cortex in all sections, but distinctly more in the control than in the experimental bone. The injection of the medulla in all sections was good.

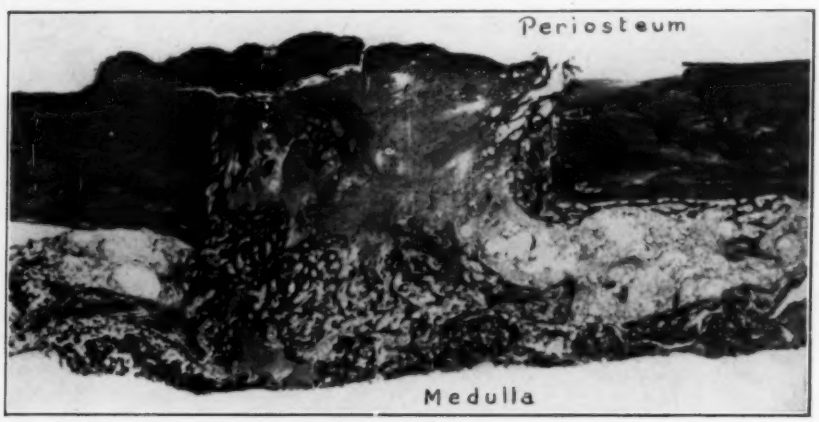


FIG. 6. 9-X-1

Group 1, Class C.—Nutrient Vessels. Two weeks' duration.
Periosteum reattached. Reaction fibrous and vascularity poor. Cortical injection very poor. Medullary responses very active and injection good, especially at central end.

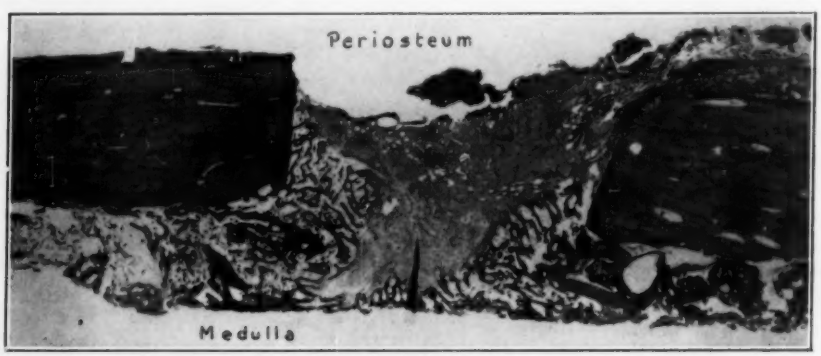


FIG. 7. 9-C-1

(Control for 9-X-1.) Periosteal reaction fibrous. Medullary response fairly active and about as advanced as 9-X-1.

CLASS C

*Group 2.* Metaphyseal. Duration, two weeks.

*Dog 8.* Right leg. Operated upon by technique 2 on May 13, 1925. Wound healed and dog was all right until May 24 when distemper developed. Sacrificed and injected on May 27.

*Gross Findings:*—Good injection of both bones. Medulla of control somewhat more densely colored than experimental, especially in middle region. Periosteum had been entirely stripped from diaphysis of experimental bone but had reattached firmly. Very marked periosteal reaction and new bone formation about nutrient foramen, which had been roughly scraped and in which bone wax had been rubbed. However, the canal was not entirely obliterated, though in all probability nutrient artery had been ruptured by trauma and scraping. Presence of ink where artery entered canal showed that vessel must have reformed and reestablished a nutrient supply before the two weeks had elapsed. Callus firmer and more prominent in experimental than in control defects.

*X-ray:*—Shadows of callus slightly denser in experimental than in control defects.

*Microscopic Notes:*—

*8-X-1.* Only one-half of defect area on slide. Cortical cells viable except in outer one-quarter. Vascularity and injection of cortex unusually good. No periosteal callus in preparation. Medullary callus very abundant and active. Much bone formation in canal, extending up to top of defect along cortical side wall but centre deeply depressed. Excellent injection of medullary vessels.

*8-C-1.* Similar to 8-X-1 in all essentials.

*8-X-2.* No periosteal callus shown. Cortical cell death only in surface layers. Fair injection cortex. Extremely marked callus formation. Defect filled from below and osteoid callus bulged out above level of cortical surface. This callus was definitely of medullary origin and indicated extreme repair activity. Vascularization and injection excellent in medulla and callus in defect.

*8-C-2.* Moderate periosteal activity. Cortex viable throughout and well injected. Defect umbilicated and topped by fibrous layer. Good medullary activity and bone formation but not comparable to 8-X-2. Excellent injection.

*8-X-3.* No periosteal reaction shown. Cortex less viable in outer layers than control but fairly well injected. Marked medullary callus formation. Good medullary injection. Defect slightly umbilicated and capped by fibrous layer.

*8-C-3.* Moderate fibrous reaction from periosteum. Cortex viable but poorly injected. Defect filled practically level with active bone-forming callus of medullary origin. Medulla very active and well injected.

*Summary, Dog 8.* From microscopic findings the defects were being repaired practically as well in the experimental bone as in the control. The medullary canal was well injected in both bones, and the gross finding of the patent nutrient artery was confirmed by microscopic evidence. It seemed probable from the degree and extent of trauma to the bone about the entrance of the nutrient vessels that these must have been ruptured but, since the foramen was not plugged with wax, that the vessels must have reformed quickly and reestablished an adequate supply via the nutrient foramen. In this case the cortical necrosis was limited to the outer fourth of the cortex, roughly speaking.

CLASS C

*Group 3.* Periosteal. Duration two weeks.

*Dog 11.* Left leg operated upon by technique 3 on May 27, 1925. Sacrificed and injected June 9.

*Gross Findings:*—Slight pus formation about wax plugs at each end of shaft but no evidence of infection around experimental defects. Wound had healed *per primum.* Good injection of both ends but medulla of shaft only very little discolored, except just at defect areas where, apparently, vessels penetrated from the outside. Externally, periosteum much thickened and defects filled with pretty firm callus. Cortex very little injected. Control showed normal injection and callus formation.

*X-ray:*—There was little to choose between the density of callus in the experimental and control tibiae.

*Microscopic Notes:*—

*11-X-1.* Marked periosteal thickening and new bone formation on surface of cortex, a short distance from edge of defect. Near edge of defect periosteal reaction fibrous in character and defect itself filled with vascular and well injected mass of fibrous tissue projecting downward. Cells viable in outer half of cortex with small viable islands deeper in, but in general, there was necrosis both of bone cells and cells in canals close to marrow cavity. In one region marrow tissue entirely necrotic, while to one side of defect circulation had been partially reestablished as cells were viable and

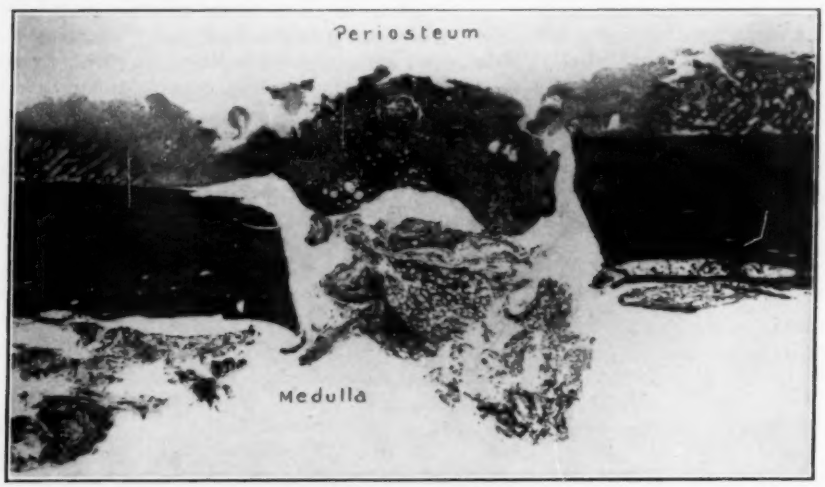


FIG. 8. 11-X-2

Group 3, Class C.—Periosteal. Two weeks' duration.

Periosteal reaction marked. Cortical injection poor and deeper layers necrotic. Defect filled with bridging callus of periosteal origin, largely fibrous. Some medullary necrosis, and bottom of defect filled with bony detritus. No medullary repair.

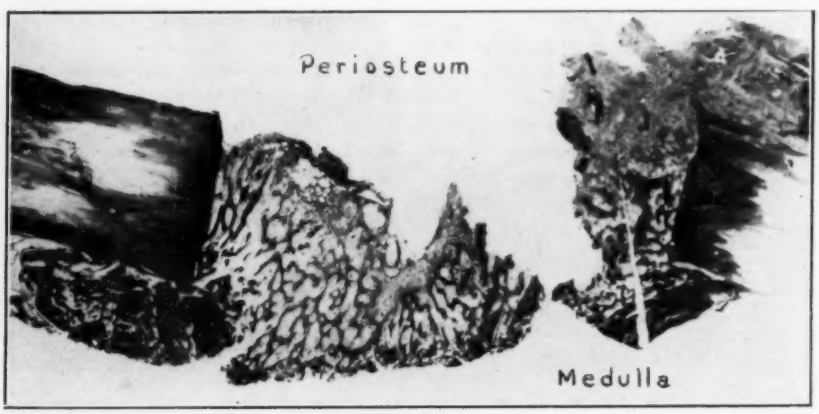


FIG. 9. 11-C-2

(Control for 11-X-2.) Moderate periosteal action. Cortex viable and well injected. Defect being repaired actively from medullary side, and medulla well injected.

showed slight reparative reaction. Medullary callus very deficient and retarded. Cell activity, where present, not as abundant as in control. Very little injection, even in region of medullary activity. Periosteal callus well injected. Cortex practically not injected. Defect filled with dense fibrous callus arising from periosteum and small amount of partially organized clot with moderate leucocytic infiltration, but from bottom only feeble attempt at callus formation from medullary side.

*11-C-1.* Periosteal reaction negative. Cells of cortex viable. Good injection of cortical vessels. Medullary tissue damaged in preparation, but defect filled with top layer of injected dense fibrous callus, of periosteal origin probably, and bottom filled with fairly advanced, well injected, osteogenetic callus.

*11-X-2.* Sections poorly cut on bias, not showing medulla well. Periosteal reaction marked with good bone formation, except close to defect where it became fibrous and dipped downward. Defect filled with well injected, vascular, fibrous tissue, showing osteogenesis only on borders of cortical walls of defect. Bottom filled with necrotic, bony detritus. Outer cortical cells viable. Deeper layers necrotic with some patches of degeneration in medullary tissue. No adequate cortical injection.

*11-C-2.* Moderate periosteal reaction, largely fibrous. Cortex viable and comparatively well injected. Defect filled with top layer of fibrous tissue, with very active osteoid callus formation of medullary origin. Medulla active and well injected.

*11-X-3.* Very poor section.
*11-C-3.* Lost in preparation. } Discarded.

*Summary, Dog 11.* (1) The medulla showed no adequate injection, either gross or microscopic. There was a good deal of necrosis, indicating a slow and insufficient collateral supply in the central region from the periosteum via the cortex, even after two weeks had elapsed. (2) Vascularization and reactivation in the medulla had been by way of vessels through the defects and were only partial after two weeks. (3) Deep cortical necrosis showed that, roughly speaking, the inner half of the cortex was dependent upon the medulla for nourishment. (4) The periosteum had been bone-forming only at some distance from the edges of the defects, while the defects themselves were filled chiefly with fibrous tissue which was being converted into bone, but only in close apposition to the side wall of the defects.

### Class D

*Group 1.* Nutrient Artery. Duration three weeks.

*Dog 5.* Left leg operated upon by technique 1 on May 2, 1925. Sacrificed May 26.

*Gross Findings:*—Marked periosteal new bone in experimental leg, especially about region of wax plugs in shaft. Nutrient artery intact and excellent injection of whole of medulla. Few small and injected vessels seen entering cortex, both from within and without, and cortex, as a whole, definitely more injected than in control. Medullary injection better in experimental than control bone. Callus in experimental defects firmer and more exuberant than in control. Periosteal reaction less in control.

*X-rays:*—Denser shadows in all defects of experimental than of control bone. This included central as well as subperiosteal shadows. Extremely dense shadows about two wax-filled defects made to block ends of medullary cavity.

*Microscopic Notes:*—

*5-X-1.* Periosteum moderately thickened and fibrous. Just a thin layer of new bone over surface of cortex. Close to defect this layer was thickened. Cortex poorly injected and almost all lacunae empty or cells degenerated. Slight viability in deeper layers of cortex. Medulla profusely injected. Marked new bone formation in medulla. Defect completely filled with cancellous callus. No fibrous central core. Very profuse and active medullary response.

*5-C-1.* Section poorly cut. No periosteal new bone shown. Cortical cells viable. Cortex poorly injected. Callus formation in defect active and advanced. Injection of medulla and callus not equal to 5-X-1.

*5-X-2.* Fair amount of periosteal new bone. Good injection of cortex which

showed necrosis only in outer third. Inner cortical layers stained well. Canals of cortex enlarged and very cellular. Defect completely filled with very advanced callus formation of medullary origin apparently. Injection of medulla excellent and large vessels seen in defect callus. Marked reparatory activity arising from medulla.

*5-C-2.* Very little periosteal reaction. Cortex generally viable. Injection cortex poor. Defect almost filled with callus of medullary origin. Injection of medulla and defect callus very poor. Repair processes not as active as in 5-X-2.

*5-X-3.* Extremely marked periosteal callus formation. Cortex viable except in outer layers. Cortical injection good. Defect more than filled with exuberant callus of both medullary and periosteal origin. Injection of medulla and defect callus excellent. Very marked and rapid repair.

*5-C-3.* Moderate periosteal reaction with osseous callus about edges of defect,

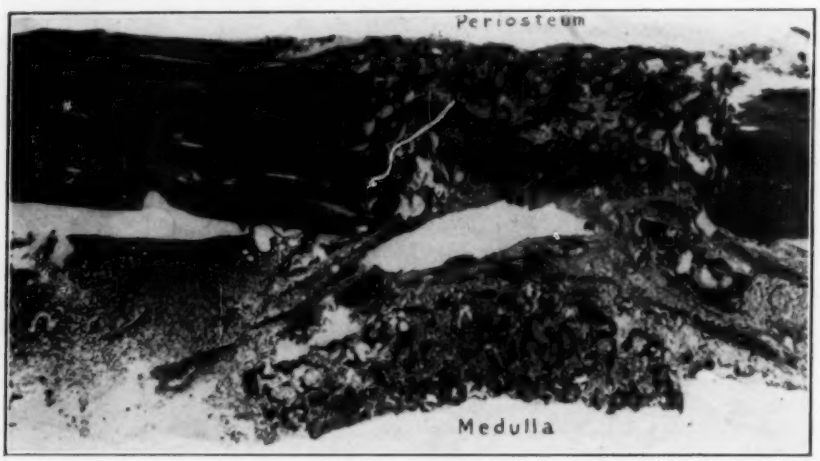


FIG. 10. 5-X-2

Group 1, Class D.—Nutrient Vessels. Three weeks' duration.
Moderate periosteal new bone. Cortex fairly well injected and canals enlarged. Medullary repair active. Defect well filled in and callus very vascular.

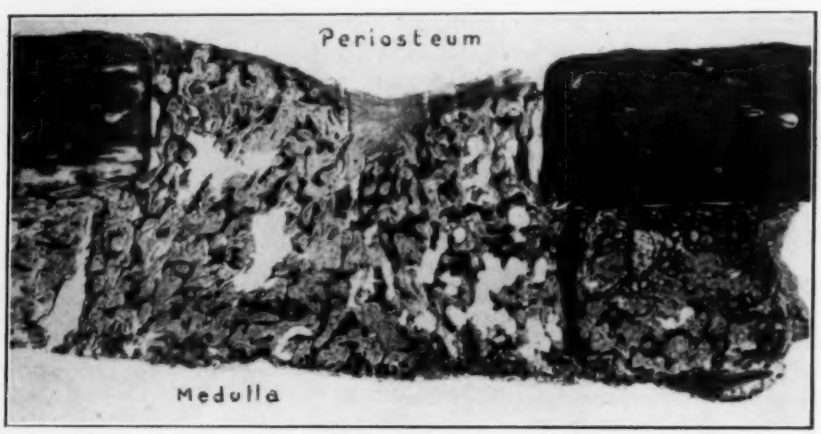


FIG. 11. 5-C-2

(Control for 5-X-2.) Little periosteal reaction. Injection cortex poor. Repair of defect not as advanced and callus more fibrous than in 5-X-2.

but in centre of defect the reaction was fibrous. Cancellous callus which almost filled defect was of medullary origin. Cortical cells viable. Callus formation distinctly less than 5-X-3, and defect still umbilicated. Injection poor throughout.

*Summary, Dog 5.* Superficial cell death in the cortex resulted from stripping of the periosteum. The periosteum had reattached and produced more new bone in the experimental than in the control defects.

The medullary reaction and injection were uniformly better in the experimental bone. The nutrient artery was shown to be an efficient source of supply for the whole medullary region, both as to viability and repair.

Compensatory hyperemia was more marked than in the experimental bone.

Cortical porosis was also more marked.

The presence of wax in the central canal seemed to stimulate periosteal new bone formation in adjoining region.

CLASS D

*Group 2.* Metaphyseal. Three weeks.

*Dog 10.* Right leg operated upon May 20 by technique 2. Sacrificed June 9.

*Gross Findings:*—Periosteum had reattached with much new bone formation all over surface of shaft. Much new bone about nutrient foramen. Nutrient artery injected, showing that this source of supply must have been reestablished within three weeks' time though post-traumatic reaction around nutrient foramen confirmed the rupture of vessel at operation. Medulla well injected throughout. Cortex only slightly injected. Virtually all of medullary cavity filled with dense callus. Control bone showed very little periosteal reaction except close to defect. Injection cortex poor. Medulla only fairly well injected. Dense callus in defects but not as marked as in experimental bone.

*X-ray:*—No marked difference between bones but the shadows were a shade heavier in experimental than in control defects.

*Microscopic Notes:*—

*10-X-1.* No periosteum shown. Cortex moderately injected from medulla. Necrosis of cortical cells limited to superficial layers. Canals widened and filled with viable cells. Defect filled from below with fairly well developed and active osteoid callus, extending about one-half way to surface. This was evidently of medullary origin and was capped by dense fibrous tissue of periosteal origin so that centre was umbilicated. Medulla filled with cancellous callus, not very far advanced. Injection fairly good and quite diffuse.

*10-C-1.* Marked periosteal new bone formation. Defect completely filled with active cancellous callus. Cortex viable and well injected. Canals enlarged. Very marked active medullary callus formation with excellent injection. Reparative activity greater than 10-X-1.

*10-X-2.* Very little periosteal reaction. Cortex poorly injected but cells viable, except in superficial layers, and scattered islands deeper. Good active medullary callus which filled defect completely and fused with fibrous periosteal covering. Injection of medulla and defect fair and proliferation seemed moderately active.

*10-C-2.* Marked periosteal new bone. Defect filled with actively proliferating cancellous bone. More activity, and repair further advanced than in 10-X-2. Cortex viable. Medulla well injected. Injection cortex good.

*10-X-3.* Some periosteal callus away from defect. Superficial layers of cortex necrotic. Cortex poorly injected but canals widened. Defect filled with actively proliferating callus arising from medulla. Medullary reaction marked. Injection of medulla and callus good.

*10-C-3.* Periosteal reaction marked. Defect filled with actively proliferating new bone. Medullary reaction very pronounced. Injection good. 10-C-3 more advanced and repair more active than 10-X-3.

*Summary, Dog 10.* There was no medullary necrosis. Injection was not as good in the experimental as in the control bone. Periosteal reaction near the defects was notably

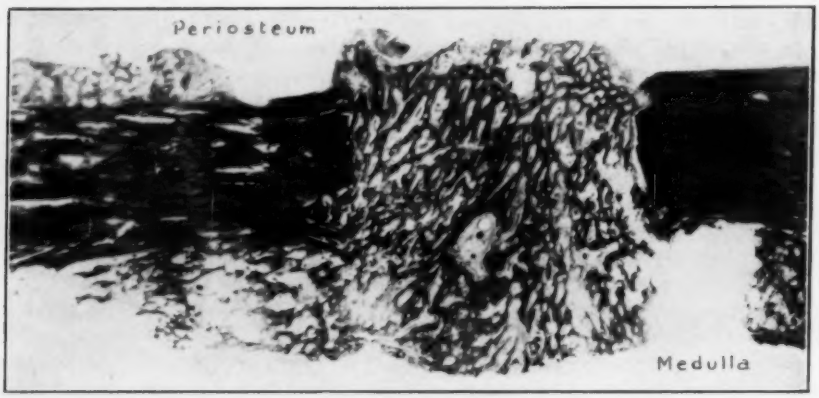


FIG. 12. 10-X-3

Group 2, Class D.—Metaphyseal Vessels. Three weeks' duration.
Fair periosteal reaction. Cortex becoming porotic. Quite active proliferation of callus and medulla.

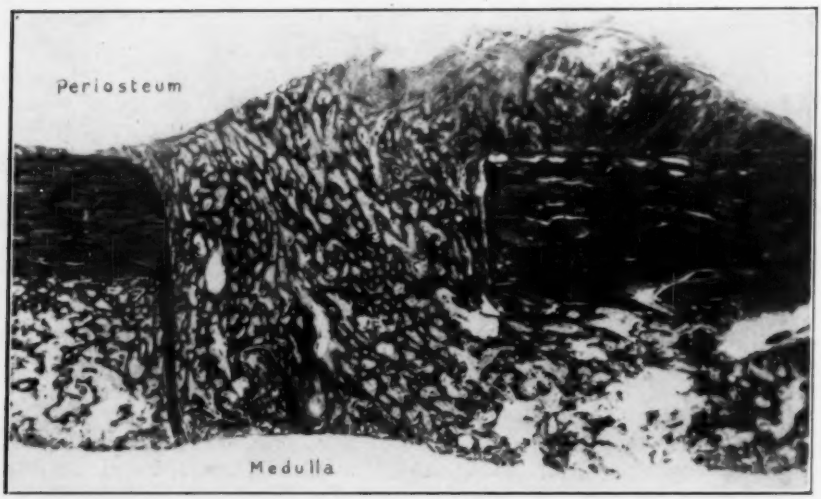


FIG. 13. 10-C-3

(Control to 10-X-3.) Very marked periosteal reaction. Medullary reaction very pronounced, and repair more active and advanced than in 10-X-3.

less in the former. Cortical necrosis was very superficial. Repair had been interfered with by temporary elimination of the nutrient supply but no necrosis had occurred, save in superficial layers of the cortex. The periosteum in the experimental bone had become reattached but played very little part in the repair of the defects.

### CLASS D

*Group 3.* Periosteal. Three weeks.

*Dog 4.* Left leg operated upon April 29, 1925 by technique 3. Sacrificed May 20.

*Gross Findings:*—At operation absence of bleeding from defects confirmed the rupture of nutrient artery. Postmortem, a great deal of periosteal new bone about nutrient foramen indicated rough periosteal stripping and avulsion of vessels, but injection showed vessels reformed and nutrient supply reestablished. Periosteal reaction not marked

except close to defects and around nutrient foramen where periosteum had been stripped. Marked periosteal reaction about wax plugs. Cortex poorly injected. Medullary injection above and including defect 2 very good. Injection about third defect poor and medulla scarcely injected at all below this point. Callus, itself, in third defect well injected. Control showed slight periosteal reaction, umbilicated defects and good normal injection of shaft and defects.

*X-ray:*—Shadows filling experimental defects denser than those in control defects, both in through-and-through and profile views.

*Microscopic Notes:*—

*4-X-1.* Very marked periosteal callus, both osteoid and cartilaginous. Callus heaped up about edges of defect. Cortical cells viable, except in some deep areas. Marked medullary callus, well advanced and actively proliferating. Defect completely filled with osteoid callus. Moderate injection of periosteal new bone. Cortex very poorly injected, though cells of canals viable. Medulla fairly well injected but callus less injected than in control.

*4-C-1.* Moderate periosteal reaction about edges of defect. Cortex viable throughout. Defect only partially filled with osteoid callus arising from medulla and capped by dense fibrous layer of periosteal origin. Defect umbilicated. Medullary callus active and injection very good. Repair did not seem as active as in 4-X-1, though injection was more profuse.

*4-X-2.* Very marked periosteal callus. Defect well bridged with thick callus layer. Cortex viable in outer third but cells in deeper layers necrotic. This cortical necrosis more marked below than above defect. Injection both of cortex and medulla good above but poor below defect. Active and advanced medullary callus. No medullary necrosis shown.

*4-C-2.* Poor periosteal callus. Cortex viable. Side walls of defect covered with callus but towards centre a funnel-shaped depression filled with dense fibrous tissue. Medullary callus not abundant. Fair injection of cortex above defect but poor below with some necrotic islands. Less active repair, both periosteal and medullary than in 4-X-2.

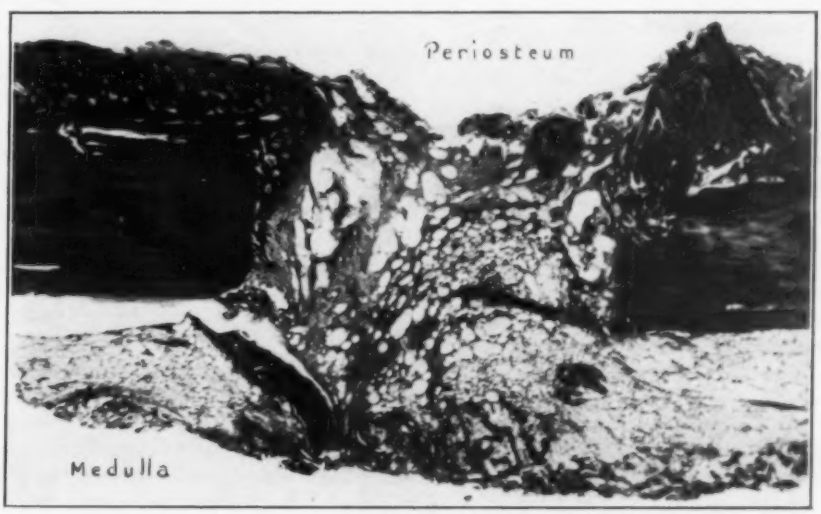


FIG. 14. 4-X-3

Group 3, Class D.—Periosteal. Three weeks' duration.

Marked periosteal reaction. Cortex poorly injected. Cells necrotic in deeper layers. Defect filled with fibrous tissue, largely of periosteal origin. Defect not filled in from medullary side. Some areas of marrow necrosis and practically no medullary repair.

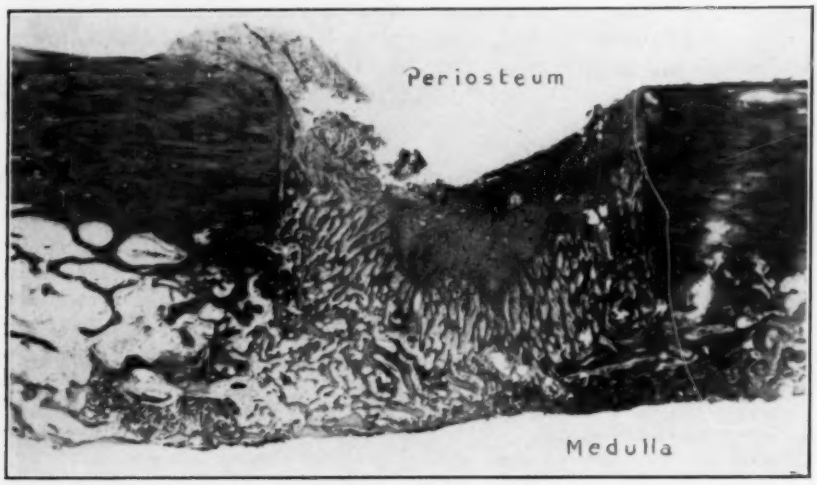


FIG. 15. 4-C-3

(Control for 4-X-3.) Little periosteal reaction. Cortex well injected. Marked medullary activity and repair of defect, especially from medullary side.

*4-X-3.* Very marked periosteal reaction. Cortex poorly injected and cells in inner two-thirds almost all necrotic. Outer layers viable. Defect filled with fibrous tissue of varying density and some fat cells. Walls of defect covered with thin layer of osteoid callus of periosteal origin. Defect not filled in from medullary side. Very slight injection of medulla. Some areas of marrow necrosis. Repair just starting from medullary side and very slight in amount.

*4-C-3.* Similar to 4-C-2. Defect about one-third filled with osteoid medullary callus covered with dense fibrous layer. Fair medullary activity but with poor periosteal response. Injection average.

*Summary, Dog 4.* The nutrient artery was only temporarily thrown out of function and soon reestablished itself, but owing to trauma and blockage at defect X-2 the conditions found at defect X-3 showed what would have been the result of permanent obstruction of this source of supply, i.e., medullary necrosis with no repair until revascularization via defects occurred. Transcortical anastomosis was most inadequate and quite negligible. Periosteal new bone formation was quite active but of little value as compared with medullary callus in repairing the cortical defect. The excellent callus at 4-X-1 and 4-X-2 showed that the nutrient supply must have reestablished itself very quickly, despite gross trauma to the vessels and foramen.

## CLASS E

*Group 1.* Nutrient artery. Four weeks.

*Dog 12.* Left leg operated upon by technique 1 on May 30, 1925. Sacrificed June 27.

*Gross Findings:*—Extreme thickening with enormous amount of periosteal new bone. Periosteal new bone remarkably uniformly laid down with maximum thickness of six mm. Nutrient artery intact and medulla well injected. Periosteal new bone very vascular and well injected. Cortex fairly well injected and just distinguishable, the medulla having been practically filled with callus and sclerotic tissue. Control bone showed good injection of medulla. Very slight periosteal thickening and far less medullary callus and sclerosis.

*X-ray:*—Clearly demonstrated excessive periosteal new bone and showed distinctly denser shadows in each defect of experimental bone than of control.

*Microscopic Notes:*—

*12-X-1.* Extreme periosteal new bone formation. Cortical cells all necrotic except where revitalization had occurred close to canals, which had been enlarged and abundantly revascularized. Cortical injection good. Defect entirely filled with advanced type of osseous callus. Injection callus and medulla very good. No medullary necrosis. Medullary callus active.

*12-C-1.* Moderately active periosteal activity. Very little cortical necrosis. Good injection of periosteum, callus and medulla. Moderate medullary callus. Defect filled at base with osseous callus, but outer portion filled with dense fibrous tissue which was slowly being changed to bone from base outward. Repair and injection much more marked in 12-X-1 than 12-C-1.

*12-X-2.* Extreme periosteal new bone formation. Cortex entirely necrotic except where recolonized close to enlarged and very vascular canals. Injection cortex very good. Medulla also very well injected. No medullary necrosis. Callus profuse and extremely active.

*12-C-2.* Marked periosteal new bone. Defect entirely filled with well advanced callus. Cortex viable. Much less cortical porosis and hyperemia than in 12-X-2. Reparatory response from medulla equal to 12-X-2.

*12-X-3.* Extreme periosteal reaction. Cortex entirely necrotic but less actively revascularized. Defect completely filled with new bone. Medulla viable and actively repairing damage.

*12-C-3.* Moderate periosteal reaction. Defect completely filled with new bone. Cortex viable but injection poor. Moderate medullary response.

*Summary, Dog 12.* The nutrient artery was sufficient, unaided, to allow very marked medullary repair. There was no medullary necrosis.

The periosteum reattached quickly and gave rise to very exuberant subperiosteal callus following the trauma of stripping.

The cortex, though necrotic, had become very porotic and extensively revascularized. The cortex in control was neither very vascular nor porotic. The possibility of a fairly extensive transcortical anastomosis between the periosteum and the medulla was shown here for the first time.

Physiological activity of the shaft had been more stimulated in the experimental bone than in the control.

CLASS E

*Group 2.* Metaphyseal. Four weeks.

*Dog 6.* Right leg operated upon on May 6, 1925 by technique 2. Sacrificed June 30.

*Gross Findings:*—Periosteum firmly attached and considerable amount of periosteal new bone all about shaft, especially behind near nutrient foramen which was much deepened. Nutrient vessels had reformed and were patent, though thickened and deeply imbedded in new bone. Defects completely filled up and hidden by periosteal new bone. Medulla fairly well injected, especially just at defects. Control bone showed fair injection but periosteal reaction only about the defects.

*X-ray:*—Much more general periosteal new bone on experimental side than on control. Slightly greater density of callus in defects on experimental side.

*Microscopic Notes:*—

*6-X-1.* Periosteum had been completely stripped in preparing specimen. Cortex very well injected. Above defect, cortical necrosis very slight and very superficial. Below defect, though injection was good, necrosis of outer third of cortex evident. Defect completely filled with well advanced and well injected callus. Medullary injection very good but cellular activity only moderate.

*6-C-1.* Very marked periosteal new bone. Defect completely filled. Injection of periosteal callus and cortex poor. Cortex viable. Medullary callus very profuse and well advanced with abundant injection. 6-C-1 showed evidence of greater medullary activity than 6-X-1.

*6-X-2.* Moderate periosteal new bone. Cortex necrotic throughout on both sides of defect. Some slight revascularization and recolonization of cortex with fair injection noted above defect. Very little activity or injection in cortex below defect. Defect filled with fairly dense callus, chiefly of periosteal origin, as proved by slight but typical

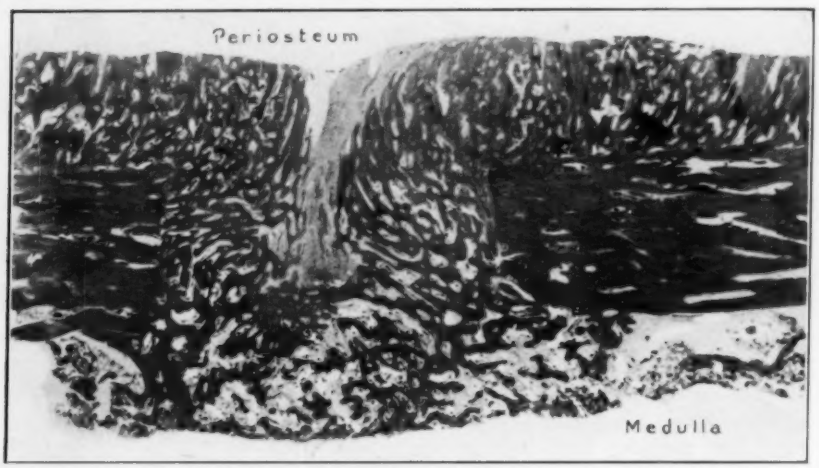


FIG. 16. 6-X-3

Group 2, Class E.—Metaphyseal. Four weeks' duration.

Extreme periosteal reaction. Outer layers cortex necrotic. Cortical revascularization advanced. Defect filled with advanced periosteal callus. Medullary tissues viable but repair not very active.

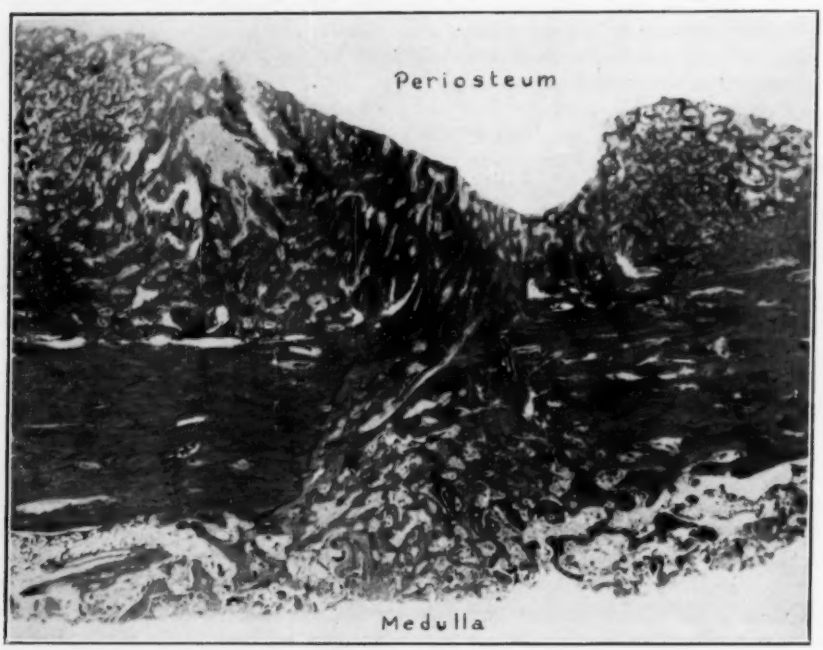


FIG. 17. 6-C-3

(Control to 6-X-3.) Marked periosteal reaction. Less cortical porosis. Active repair, both periosteal and medullary in origin.

central depression and several large vessels in fibrous tissue penetrating to medulla through defect. No medullary necrosis seen. Medullary repair distinctly delayed and not so profuse or active as in control, though injection of vessels was fairly profuse.

*6-C-2.* Extremely active periosteal proliferation. Cortex all viable and well injected. Defect completely filled with advanced and active new bone. Medullary response active.

*6-X-3.* Extremely marked periosteal new bone. Cortex necrotic in outer portion, though canals well stained. Some areas of recolonization. Cortex somewhat porotic and well injected. Defect filled with callus which had fibrous tongue extending down into it, indicating that it arose from periosteum and was vascularized from without. Medullary callus formation not extensive nor profuse. Injection of medulla poor.

*6-C-3.* Very great periosteal new bone formation. Cortex viable and injection good. Defect filled with well advanced callus. Injection of callus and medulla fairly good. Medullary callus well advanced and active.

*Summary, Dog 6.* In the experimental bone the medullary repair was evidently delayed. In 6-X-2 and 6-X-3 there was a down growth of periosteal callus into the defects carrying large vessels with it from the outside. This was not seen in the controls and indicated a marked impairment of the normal medullary response and an inability to build up callus and fill the defects rapidly from below.

The medulla was nowhere necrotic, indicating a sufficient collateral blood supply via the metaphysis to prevent medullary cell death in the shaft.

The nutrient artery had reformed and was again active in supplying the medulla, which had evidently increased its repair activity with the increased vascularity.

Cortical cell death was quite well marked in the outer layers of the cortex, near the ends of the diaphysis, and was very complete in the middle defect which was farthest from the metaphyseal supply. The cortex, however, was everywhere becoming porotic and was being actively revascularized and revitalized at this comparatively early time.

### Class E

*Group 3.* Periosteal. Four weeks.

*Dog 7.* Right leg operated upon on May 9, 1925 by technique 3. Sacrificed June 8—four weeks and two days.

*Gross Findings:*—Very little periosteal new bone formation about shaft generally. Marked reaction in periosteum at region of central wax plug at each metaphyseal region. Marked periosteal reaction about edges of each defect and nutrient foramen where it had been stripped to rupture artery. Nutrient vessels reformed and deeply imbedded in periosteal new bone. Three defects completely filled and leveled off. Medulla fairly well injected but filled with rather dense tissue and callus. In control bone there had been a subperiosteal fracture through defect 2 which had altered the gross appearance by causing a fusiform callus to be thrown about central part of shaft. In control defects C-1 and C-3 the callus formation was less exuberant than in the experimental defects. Injection of control more profuse.

*X-ray:*—Confirms gross and shows clearly the fracture line through control defect 2.

*Microscopic Notes:*—

*7-X-1.* Lost in preparation.

*7-C-1.* Moderate amount of periosteal new bone formation. Cortex entirely viable but poorly injected. Moderate amount of medullary new bone which was well advanced. Defect not quite filled, just a slight depression filled with dense fibrous tissue. Medulla fairly well injected.

*7-X-2.* Extremely marked periosteal new bone about edge of defect. Periosteal callus well injected. Cortical cells all necrotic, except extremely superficial layers. Cortex invaded from above and below by ingrowth of vascular tissue which gave fair injection in enlarged cortical canals. Recolonization of bone lacunae close to enlarged vascular channels. Medullary callus profusely formed and actively proliferating. Medullary injection excellent. Defect filled to over-flowing with well advanced cancellous

callus of both periosteal and medullary origin, though, apparently, periosteal callus predominated.

*7-C-2.* Extremely marked periosteal reaction with massive new bone formation. Cortical cells generally viable. Cortex poorly injected. Defect filled to over-flowing and medullary reaction of profuse and advanced type. Medullary injection relatively poor. It seemed fair to attribute the extreme periosteal reaction at 7-C-2, as compared to 7-C-1 and 7-C-3, to the fracture of the shaft that occurred through this defect.

*7-X-3.* Extremely marked periosteal reaction. Cortex only fairly well injected. Cortical necrosis except surface layers. Medulla showed a few small areas of necrotic detritus but, in general, injection good and medullary new bone formation active. Defect completely filled with poorly injected new bone.

*7-C-3.* Moderately active periosteal callus. Cortex viable throughout. Poor injection of cortex. Periosteal injection good. Defect filled with well advanced callus. Medullary injection and activity very good.

*Summary, Dog 7.* The periosteal reaction was markedly hyperactive only about the regions traumatized by stripping, or at the site of a fracture, as at 7-C-2, or when irritated by the presence of some foreign substance, such as the metaphyseal wax plugs in

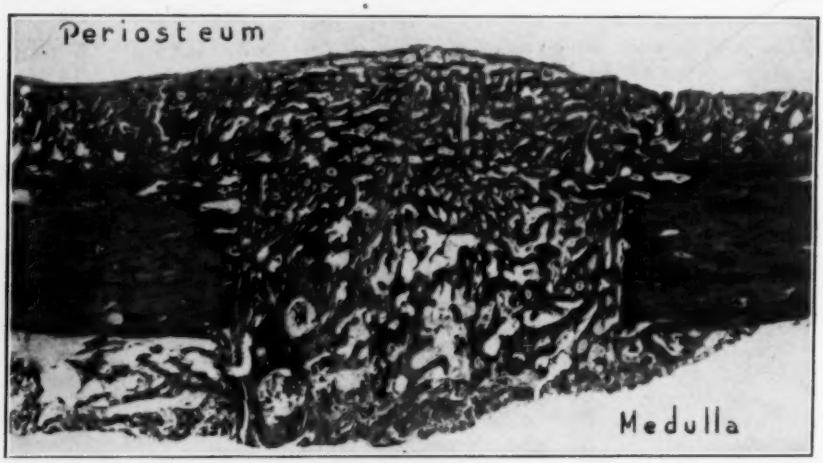


FIG. 18. 7-X-3

Group 3, Class E.—Periosteal. Four weeks' duration.
Marked periosteal new bone. Cortical necrosis except at surface. Cortex only fairly well injected. Defect completely filled in with advanced callus.

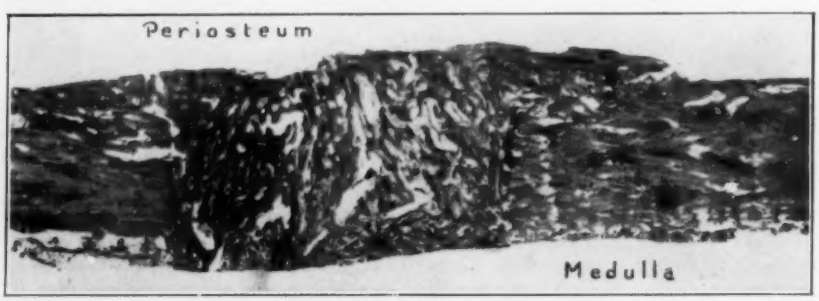


FIG. 19. 7-C-3

(Control to 7-X-3.) Moderate periosteal response. Defect completely filled in. Cortical injection poor. Medullary injection and activity good.

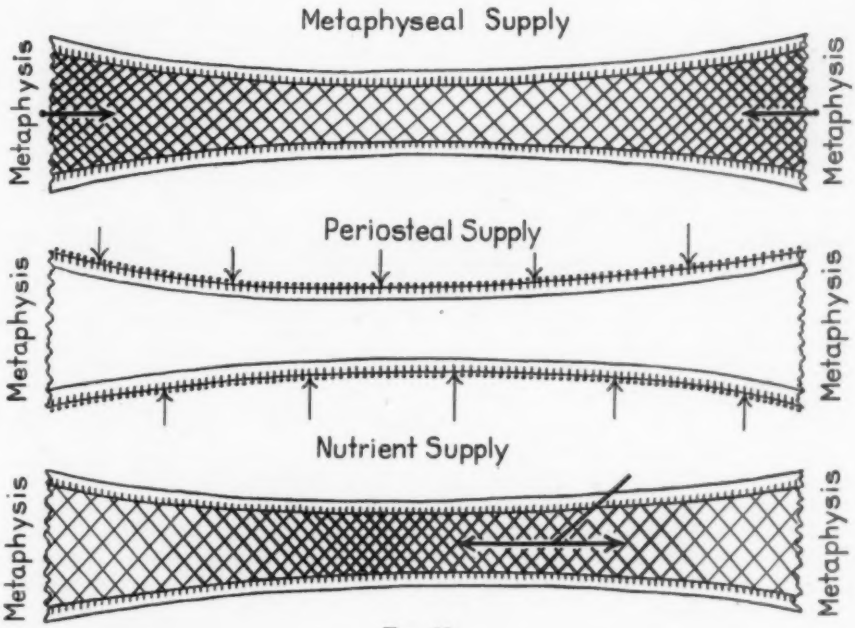


FIG. 20

this case. The nutrient artery reformed rapidly in this experiment in spite of our efforts to block the foramen with a wax plug.

The defects were all filled with bony callus of well advanced type, but the controls were not as active.

The medullary circulation was cut off temporarily in the experimental bone, as shown by the cortical necrosis of all save the superficial layers, but the medullary supply was reestablished in time to prevent extensive medullary necrosis and not to delay central callus formation greatly. The injection of the medulla and the defect callus was quite good despite temporary blockage.

## BIBLIOGRAPHY

LEXER, E.: Die Entstehung entzündlicher Knochenherde und ihre Beziehung zu den Arterienversweigungen der Knochen. Arch. f. klin. Chir., LXXI, 1, 1903.

LEXER, E., KULIGA AND TURK.: Untersuchungen uber Knochenarterien. Hirschwold, Berlin. 1904.

LEXER, E.: Blutige Vereinigung von Knochenbrüchen. Deutsch Ztschr. f. Chir., CXXXIII, 170, 1915.

LEXER, E.: Über die Entstehung von Pseudarthrosen nach Frakturen und nach Knochentransplantationem. Arch. f. klin. Chir., CXIX, 520, 1922.

MACEWEN, WM.: Development and Growth of Bone. Brit. Med. J., II, 766, 1912.

MARTIN, B.: Über Regeneration der Röhrenknochen. Arch. f. klin. Chir., CXIII, 1, 1920.

MARTIN, B.: Zur Knochenregeneration aus dem Periost. Arch. f. klin. Chir., CXX, 744, 1922.

MARTIN, B.: Über experimentelle Pseudarthrosenbildung und die Bedeutung von Periost und Mark. Arch. f. klin. Chir., CXIV, 664, 1920.

DAX, R.: Über die Beziehungen der Zirkulationsstörungen zur Heilung von Frakturen der langen Röhrenknochen mit besonderer Berücksichtigung der Arteria nutritia. Beitr. z. klin. Chir., CIV, 313, 1916–17.

BIER: Experimentelle Erfahrungen über Pseudarthrosenbildung. München Med. Wchnschr., LXVII, 222, 1920.

MÜLLER, W.: Die Normale und Pathologische Physiologie des Knochens. Leipzig, J. A. Barth, 218, 1923.

ROHDE, C.: Über den Ablauf der Regenerationsvorgänge am Röhrenknochen bei erhaltener und geschädigter Gefässversorgung, zugleich ein Beitrag über Herkunft und Entstehungsbedingungen des Bindegewebes nach Knochenverletzungen. Arch. f. klin Chir., CXXIII. 530, 1923.

DRINKER, C. K., DRINKER, K. R. AND LUND, C. C.: The Circulation in the Mammalian Bone Marrow. Am. J. Physiology, LXII, 1, 1922.

PINEY, A.: The Anatomy of the Bone Marrow. Brit. Med. J., II, 792, 1922.

BANCROFT, F. W.: Bone Repair Following Injury and Infection. Arch. Surg., V, 646, 1922.

DOAN, C. A.: The Capillaries of the Bone Marrow of the Adult Pigeon. Bull. Johns Hopkins Hosp., XXXIII, 222, June 1922.

GIRDLESTONE, G. R.: The Union and Consolidation of a Fracture. Am. J. Surg., XXXVIII, 129, June 1924.

BROOKS, B.: Studies in Regeneration and Growth of Bone. Ann. Surg., LXV, 704, June 1917.

GALLIE, W. E. AND ROBERTSON, D. E.: The Repair of Bone. Brit. J. Surg., VII, No. 26, 211, 1919–20.

BROOKS, B. AND HUDSON, W. A.: Studies in Bone Transplantations. Arch. Surg., I, 284, Sept. 1920.

ALLISON, N. AND BROOKS, B.: Bone Atrophy. Surg. Gynec. Obstet., XXXIII, 250, Sept. 1921.

GROVES, E. W. H.: The Repair of Bone Injuries. Bristol Med.-Chir. J., XXXVIII, 1920–21.

ELY, L. W.: Experimental Study of the Healing of Fractures. Arch. Surg., V, 527, 1922.

NATHAN, P. W.: The Biology of Bone Development in Its Relation to Bone Transplantation. New York Med. J., CXIV, 454, 1921.

HAAS, S. L.: Regeneration of Bone from Periosteum. Surg. Gynec. Obst., XVII, 164, 1913.

HAAS, S. L.: Regeneration of Cartilage and Bone. Surg. Gynec. Obst., XIX, 604, 1914.

HAAS, S. L.: Spontaneous Healing Inherent in Transplanted Bone. Bone and Joint Surg., IV, 209, Apr. 1922.

IMBERT, L.: Le Mécanisme de la formation du cal. Presse. méd., XXIX, No. 41, 403, 1921.

LERICHE, R. ET POLICARD, A.: Le Périoste et son Role dans la Formation de l'Os. Presse méd., XXVI, No. 16, 143, 1918.

ADAMS, W. R.: Bone Grafting. Surg. Gynec. Obstet., XXXVI, 97, 1923.

CAMPBELL, W. C.: Treatment of Ununited Fractures. Am. J. Surg., XXXVII, 1, Jan. 1923.

HOWLAND, J. AND KRAMER, B.: Factors Concerned in the Calcification of Bone. Arch. Ped., XXXIX, 400, 1922.

PAGE, C. M. AND PERKINS, G.: Some Observations on Bone-Grafting. Brit. J. Surg., IX, No. 36, 540, 1921–22.

NUSSBAUM, A.: Beziehungen der Knochengefässe zur akuten Osteomyelitis. Zentralbl. f. Chir., XLIX, 700, 1922.

KOLODNY, A.: The Periosteal Blood Supply and Healing of Fractures. J. Bone and Joint Surg., V, 698, Oct. 1923.

PETERSEN, H. A.: A Clinical Study of Ununited Fractures with Special Reference to the Inorganic Bone-forming Elements in the Blood Serum. J. Bone and Joint Surg., VI, 885, Oct. 1924.

# News Notes

It is with great regret that the *Journal* has to announce the loss of one of the members of the Association, Dr. Walter Baldwin, who died at Santa Barbara on November 28 at the age of 41. Dr. Baldwin was called to the chair of the Orthopaedic Surgery in the University of California, and to the position of Orthopaedic Surgeon at the hospital connected with the University at the time of his graduation from his house surgeonship at the Massachusetts General Hospital in Boston. It was rather an unusual responsibility placed upon a man of his years, and particularly since it was at the time of the reorganization of the school and the hospital staff. He brought to it an unusual degree of native ability, added to which there had been the practical experience in the line of work which he had chosen for his life service. Under his direction and guidance the department of which he was Chief developed, and the work which he was able to carry on, has proved the wisdom of the choice in placing him to fill this position. His contact with the students was always inspiring, and he has left his influence on the many classes that have passed through the school while he filled a position in the University.

At the time of the War, Dr. Baldwin was one of the number who early went to England and worked with the British. For a long period he was stationed in Edinburgh under Sir Harold Stiles, and later went to France and was working with the other members of his own group. At the end of the War he returned to his duties in the School and the Hospital in San Francisco, where his career has been particularly promising. His early death removes from the medical profession in the West a man on whom much reliance had been placed, and his loss will be keenly felt, both by the profession, and by his large clientele of private patients, as well as among his many friends.

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The office of Dr. Lawrence K. McCafferty was moved on October 1 from 30 West 59th Street to 114 East 62nd Street, New York City.

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Dr. Solomon D. David has recently moved his office to Suite 909–910 Medical Arts Building, Houston, Texas.

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Dr. E. E. Hussey of Fall River, Massachusetts, has moved his office from 122 Purchase Street to the Archer Building, 38 Rock Street.

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Dr. Charlton Wallace has recently moved his office to 49 East 51st Street, New York City.

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Dr. Richmond Stephens announces the removal of his office to 121 East 60th Street, New York City.

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The International Society for Crippled Children will hold its annual meeting at the Sinton Hotel, Cincinnati, Ohio, February 15, 1927. Dr. F. D. Dickson of Kansas City, Missouri, will make the principal address relative to orthopaedic surgery.

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The Faculty of Medicine of the University of Vienna arranges courses of lectures in German each year. The syllabus of the courses for the year October 1, 1926 to September 30, 1927 may be obtained from the Kürsbureau of the Vienna Faculty of Medicine, Schlosselgasse 22, Wien VIII, Austria.

One of the subscribers to the *Journal* is anxious to secure the following issues:

January 1919
August 1920
January, February, March and April 1921
January and April 1922

If anyone has copies of these issues which he is willing to dispose of, please correspond with the Editor.

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John Fraser, M.C., F.R.C.S., Professor of Clinical Surgery of the University of Edinburgh and late Surgeon-in-chief to the Children's Hospital of that city, visited Toronto on October 23 and 24, 1926. He accompanied the staff of the Hospital for Sick Children on their usual weekly rounds of the wards on the morning of the twenty-third. A luncheon was tendered to him by the Academy of Medicine on this date and following the luncheon he addressed the Academy. He was the guest of Dr. W. E. Gallie over the week end.

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The annual meeting of the **Seattle Orthopaedic Society** was held on September 10 and 11, 1926, in Seattle. The Society had as its guest, Dr. Willis C. Campbell of Memphis, Tennessee, who conducted the clinics on the mornings of those days and on both evenings lectured on the various phases of reconstructive surgery, particularly arthroplasties of the knee and hip and the reconstructive operation of the hip. The meeting was well attended this year; many doctors from the states of the Northwest as well as from Canada and Alaska were present.

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The following were elected corresponding members of the **British Orthopaedic Association** on September 16, 1926:

Dr. J. van Assen Jzn., 103, Westersingel, Rotterdam.
Dr. J. W. P. Fransen, 1, Heerensingel, Groningen.

At a meeting on November 4 the following were elected members of the Association:

*Full Member* E. P. Brockman, F.R.C.S., 40, Queen Anne Street, London, W.1.

*Associate Member* B. L. McFarland, M.D., 32, Greenheys Road, Wallasey, Cheshire.

In the last issue of the *Journal* announcement was made of the election of Dr. Clarence L. Starr of Toronto as a corresponding member of the Association. The notice should have indicated that he was elected as an honorary member of the Association.

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**The Minnesota Orthopaedic Club** held its regular meeting at Duluth on October 2, 1926. The program included the following:

Demonstration by operation of the Orr method of treatment of osteomyelitis and infected compound fractures. Five cases were presented by Dr. H. Winnett Orr.

Treatment of mediastinal abscesses due to vertebral caries. A paper presented by Dr. A. Steindler.

Moving pictures presented by Dr. H. Winnett Orr illustrating: (1) use of fixed traction cast in fractures of femoral and tibial shafts, (2) Orr method of treatment of osteomyelitis and end results.

The discussion was led by Drs. Melvin S. Henderson, E. S. Geist, J. R. Kuth and C. A. Reed.

The next meeting of the club will be held in St. Paul in January.

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**CLINICAL ORTHOPAEDIC ASSOCIATION, DETROIT, MICH., NOVEMBER 5 AND 6**

The meeting of November 5 opened at 9 o'clock at the Receiving Hospital and about one hundred men were present. Dr. A. D. LaFerte showed a number of cases of fracture of the long bones, operated upon by the open method, after the method of

closed reduction had failed. He stated that he rarely put any foreign body on the bones at open operation, depending entirely on notching the ends of the bones, with fixation by plaster and muscle pull.

At 10:30 the meeting adjourned to the Harper Hospital where a case was shown by Dr. Max Ballin of a very extraordinary infection of the shoulder joint, following an operation for a reefing of the capsule with silk and in which, two years after, there were sinuses still discharging a mass of material resembling macerated black blotting paper with foul odor. This material according to Dr. Morse, pathologist, consists of living elastic and fibrous tissue, which proliferates freely under the stimulus of an infection in which the bacilli of the proteus group are the most prominent. Cases were also shown by Dr. Kidner, Dr. Morse, Dr. Evans and Dr. Funsten.

The members then proceeded to the Children's Hospital of Michigan, where cases were shown by Dr. Kidner, Dr. Funsten, Dr. Curtis, Dr. Watson, Dr. Muro and Dr. Purcell. The discussions following were particularly interesting. In the afternoon at 4:00, the meeting adjourned to the Henry Ford Hospital where cases were shown by Dr. Peabody of the orthopaedic department, and Dr. McClure. Dinner was served in the evening following which at the Annual Meeting, Dr. Meyerding was elected president, Dr. W. G. Stern vice-president, Dr. Funsten secretary and treasurer, and new members were elected to the Society, making a total membership of 149. A report of the Committee on the treatment of osteomyelitis was given by Dr. Gaenslen. It was the conclusion of the Committee that the method prescribed by Dr. Orr was satisfactory in most cases.

Saturday morning the meeting was held at Ann Arbor, where Dr. Hugh Cabot described the method of organization of the surgical department at the University of Michigan. He said that the orthopaedic department was a large part in the surgical organization, and he felt that all surgical specialties should be a part of the surgical department, as was the case at Ann Arbor, since such a relationship led to closer contact among the men practising surgery, and a better result with the patients.

Dr. Badgley, in charge of the orthopaedic surgery, gave a clinical demonstration of a number of cases, which were carefully worked up, and the amount of material was apparently very large. Dr. Yeoman discussed the treatment of infectious arthritis by the means of intravenous injection of the ammonium salt of iodolybenzoic acid, 1% in 100 c.c. doses. His claims were not extravagant, but most of the cases were definitely benefited. He showed a series of cases which evidently were of infectious or traumatic origin, in which synovectomies had been done with good results.

In the afternoon at the Convalescent Home of the Children's Hospital, Dr. Kidner and Dr. Muro demonstrated cases of tuberculosis of the spine in which practically all had gone on to complete bony fusion. Half of them had been operated on by the Hibbs' method, and the other half were unoperated; all had been kept under control. Dr. Kidner stated that there had been no more rapid progress in the operated cases than in the unoperated, and made a plea for the treatment of tuberculosis of the spine in complete recumbency.

## THE BRITISH ORTHOPAEDIC ASSOCIATION

### NINTH ANNUAL MEETING

A meeting of the British Orthopaedic Association was held in London on October 22 and 23. The first morning meeting took place at the house of the Royal Society of Medicine.

After the short business session, Mr. H. A. T. Fairbank, the President, gave an address on "Some general affections of the skeleton, including achondroplasia, osteogenesis imperfecta, and osteomalacia". He showed a large number of clinical photographs and radiograms illustrating the various points in the correlation of certain of these obscure bone conditions.

### DISCUSSIONS ON INJURIES OF THE CARPUS

The subject for discussion at the morning session was injuries of the carpus. Mr. Max Page, who opened, commented on the fact that the knowledge of this complicated subject was of comparatively recent date. He quoted largely from Mouchet, Destôt and Kellogg Speed, and presented a simplified classification based on the findings of the French school. He dealt in some detail with the treatment and prognosis. Mr. S. T. Irwin gave a careful analysis of the records of the Royal Victoria Hospital, Belfast, during a five-year period. He reported the incidence of each particular fracture, the period of disability, and the functional end result. Mr. Harry Platt suggested a classification, similar to that of Mr. Page and reported in detail the results of carpal injuries from his fracture clinic at Ancoats Hospital, Manchester, over a period of five years Mr. Thurstan Holland, Mr. Ollerenshaw, Mr. R. C. Elmslie and Mr. St. J. D. Buxton carried on the discussion. Sir Robert Jones gave the results of his great experience, and described the treatment he was accustomed to employ. He said that, with a fractured scaphoid, if the wrist moved freely under anaesthesia, he immobilized it for three weeks in dorsiflexion, and the end result was good. He had found that if the wrist did not move easily under the anaesthetic, prognosis was less good. He did not consider that removal of the whole or part of the scaphoid, although sometimes necessary, resulted in a perfect hand.

### CLINICAL MEETING

A clinical meeting on Friday afternoon was held at St. Thomas's Hospital. Two operations were first performed, Mr. Bristow removing a torn cartilage from the knee joint and Mr. Page performing arthrodesis of the hip. Then followed a clinical demonstration. Mr. Bristow showed a group of patients treated in the orthopaedic department of the hospital, illustrating points of interest in the surgery of the joints and bones. The first group illustrated the results obtained from modified arthroplasty of the hip, the reconstruction operation devised by Whitman—namely, excision of the head, remodelling of the neck, and lowering of the trochanter; three patients upon whose hips arthrodesis had been performed were shown for comparison. Four patients illustrated the end results of the treatment for recurrent dislocation of the shoulder: one cured by a deltoid muscle sling, one by repair of the glenoid ligament after the Clairemont-Erlich operation had failed; the other two patients were cured by a bone operation to raise the rim of the glenoid fossa, the glenoid ligament being found torn and so shrivelled as to be incapable of repair. Two patients illustrated reconstruction of the elbow joint, and one in whom a fractured internal epicondyle had been removed from the interior of the joint. This patient, whose elbow was stiff for some long time, had recovered full movement. Two patients in whom arthrodesis of the ankle joint had been done for old malunited Pott's fracture were shown walking well and without pain. Other patients illustrated the result of repair of muscle and tendon, bilateral rupture of the ligamentum patellae repaired by a free fasciae graft, and bilateral rupture of the quadriceps by transplantation of tensor fasciae femoris to the patella. Cases were shown of chronic sclerosing osteomyelitis (Garre), fibrocystic disease of the neck of the femur dealt with by curetting and grafting, haemophiliac knee, and adolescent coxa vara treated by open operation. A group of patients with affections of the knee joint were demonstrated, illustrating the end results after synovectomy, and patellar-femoral arthroplasty. Mr. Page showed two patients in whom he had removed five inches of bone from the femur to shorten the leg, and a patient who was cured of a clicking jaw by the removal of the interarticular cartilage.

The members were entertained at tea in the Shepherd Memorial Hall by the kind invitation of Miss Lloyd Still, the matron of St. Thomas's Hospital, after which a short visit was paid to the orthopaedic wards. Dr. J. B. Mennell then gave a demonstration in the massage department of the methods he employed in manipulating the joints. He explained the various points of his technique.

### THE ASSOCIATION'S DINNER

In the evening a most successful dinner was held at the Café Royal. Mr. Fairbank, the President, was in the chair, and some eighty members and their guests were present. His Majesty King Manuel, the most distinguished honorary member of the Association, made a graceful speech in response to the toast of his health. Sir Arthur Stanley, treasurer of St. Thomas's Hospital, replied, in a witty speech, to the toast of the guests, which had been proposed by Sir Robert Jones. Sir John Bland-Sutton proposed the health of the Association, and the President replied. Professor Murk Jansen, of Leiden then proposed the health of the President. The guests of the Association included Sir Arthur Stanley, Sir George Makins, Sir John Bland-Sutton, Sir James Berry, Sir Cuthbert Wallace, Sir Dawson Williams, Sir Squire Sprigge, and many other distinguished members of the profession.

### SHORT COMMUNICATIONS

Saturday morning was devoted to short papers. Mr. E. P. Brockman reported several cases of renal rickets, and showed a series of radiograms. He also showed a tibia from one of the patients and for comparison the tibia from a rachitic patient, and a normal tibia from a child of the same age. He had investigated the microscopic changes about the growth disc, and exhibited a series of colored drawings illustrating the changes which he had found. The President warmly congratulated Mr. Brockman on his paper. Mr. Perkins reported the end results of the operation of excision of the head of the first metatarsal bone in fifty patients, from the Orthopaedic Department of St. Thomas's. He found that from the patient's point of view the operation gave a good result in ninety-six per cent. of cases. He called attention to the fact that pain about the forefoot was not relieved by excision of the head, and that free mobility must be restored to the toes. He suggested that the bad results associated in the mind of some surgeons with this operation were due to coexisting pain about the forefoot, and that treatment for the two conditions should be simultaneously undertaken. Mr. Perkins' paper was discussed by Professor Murk Jansen, Messrs. Openshaw, Mitchell of Belfast, Elmslie, Trethowan, Rocyn Jones, and others. Mr. Lambrinudi described an operation which he had devised for the cure of paralytic drop-foot, and showed two patients. Mr. Brockman reported a case of femoral aneurysm arising in a boy suffering from Pott's disease of the spine. He exhibited the vessel which had been excised by Sir Cuthbert Wallace, and a microscopic section of the artery wall showing local tuberculous disease. Mr. Brailsford of Birmingham showed radiograms of the spine from patients illustrating spondylolisthesis erosion of the bodies caused by aneurysm and the localization of a foreign body. Owing to shortness of time, papers by Mr. Max Page, Professor Murk Jansen, and Mr. Barnett, which were to have been presented, were taken as read.

### VISIT TO OPEN-AIR HOSPITAL

On Saturday afternoon some forty members visited St. Nicholas's and St. Martin's Orthopaedic Hospital at Pyrford in Surrey. This open-air hospital of 160 beds, which belongs to the Waifs and Strays Society, is staffed by the Orthopaedic Department of St. Thomas's Hospital and Dr. T. M. Hardy of Byfleet, who is the local medical officer. Members were shown round the hospital and visited the open-air wards, after which a clinical demonstration was given. A number of patients were exhibited, including a group of eight cases of pseudocoxalgia with serial radiograms showing the various changes over a three-year period, and for comparison two patients with flattening of the head of the femur and cavitation of the neck. An informal discussion was kept up during the demonstration.

## CLINICAL CONFERENCES AT THE HOSPITAL FOR RUPTURED AND CRIPPLED, NEW YORK CITY

### CONFERENCE OF SEPTEMBER 23, 1926

The President, Arthur Krida, in the chair.

DR. WHITMAN—Case of Legg-Perthes' Disease.

Dr. Whitman presented a case illustrating the operative treatment of the so called Legg-Perthes' disease.

The patient, a boy twelve years of age, was brought to the hospital for discomfort in the left hip on exertion and an increasing limp of about four years' duration. On admission to the hospital it was noted that the patient was in good condition. The left limb was adducted somewhat, causing apparent shortening, and was slightly flexed. There was no evidence of active disease. The x-ray picture showed flattening and distortion of the head of the femur and a corresponding obliquity of the upper border of the acetabulum. As it was evident that a subluxation would soon follow, operative intervention was decided on.

The joint was opened in the usual manner for a reconstruction operation. The trochanter was removed and the head of the femur extruded. It presented a likeness to the back of a spoon, the cartilage extending from the flattened articulating extremity to the trochanter, presenting an irregularity about the margins similar to that of arthritis deformans. The acetabulum was indented and somewhat irregular at its outer and upper margin. The head of the bone was reshaped to an oval contour, almost all the cartilage being removed. The trochanter was then transplanted to the outer border of the shaft in the usual manner, the object being to assure the attitude of abduction and thus to prevent further erosion and displacement. It may be noted that there was no sign of past inflammation. The epiphyseal cartilage had disappeared and the bone was more compact than normal. The picture suggested progressive changes in the joint, secondary to deformity of the head of the femur probably induced by weakening of its structure.

DR. R. KAHLE—Traumatic Myositis Ossificans of Quadriceps.

Dr. Kahle presented the case of a man who was brought to the hospital in an ambulance on February 8, 1926. He was unable to walk, due to a fall a half-hour before. He stated that his left knee and foot turned under his body and he crumpled to the floor, something giving way in his left knee.

Past history was negative except that he fell twenty years ago, while in Italy. He thinks the left "knee cap" had been fractured. He wore a splint on the left leg for a short time and gradually gained full power of his left knee joint. He did not remember that it was swollen at any time after this injury.

Physical examination showed a well nourished man, who speaks English brokenly. He is in good condition except that he is unable to walk because the left knee gives way under his weight. There is slight swelling of the knee joint on the left and it measures 16½ inches while the right measures 15½ inches. The patella is mapped out about normal size. It is not riding on fluid. There is a gaping area into which two fingers can be laid on the inner upper side of the patella. The upper border of this area feels bony hard about the size of another patella. This gap increases on extension of the knee. This area is very tender. He is unable to extend the leg on the thigh in the recumbent position.

X-ray of February 11, 1926 is negative for recent or old fracture of patella. Numerous areas of calcification above patella in region of quadriceps muscle, tendon or bursa. Several small areas nearer patella also.

Operation, February 12, 1926. Through a long incision partly circumscribing the inner border of the patella, the subcutaneous tissues were dissected free and the patella exposed. No fracture was seen. The quadriceps tendon was entirely torn away from the patella on the inner side and only a few tendon strands remained intact on the outer side. Several blood clots were removed from the knee joint. A bony mass as

seen in x-rays was found in the patella tendon and in the lower muscle fibres of the quadriceps muscle which moved freely with it over the femur beneath. Texture was similar to bone. Two holes were then drilled through the upper third of the patella, one on the inner border and the other on the outer. Then with a needle threaded with kangaroo tendon of heavy type passing through each hole and through the quadriceps tendon, the patella was pulled back into its normal position and was fastened more securely with other interrupted chromic catgut sutures. Tension was made on the patella and it remained securely in position. Subcutaneous sutures of No. 1 plain catgut were used. Skin sutures of the same of the continuous type were used. The knee was immobilized in plaster-of-Paris bandage from ankle to groin in extension.

Convalescence was normal and uneventful. Plaster-of-Paris bandage was removed in four weeks and fifteen degrees of voluntary flexion was found to exist. He could extend the knee completely. Daily manipulation was instituted and he was walking in the sixth week. He has received physiotherapy treatment to date.

Result: Extension complete; flexion to seventy degrees; lateral stability good. The calcified tissue in the quadriceps tendon remains as evidenced clinically and by x-ray.

Dr. P. W. Roberts—Trauma of the Sacral Joints.

In the absence of the patient, the history and the x-rays of this case of trauma of the sacral joints were presented by Dr. Roberts because of the simultaneous injury of both the sacro-iliac and lumbosacral joints, with acute symptoms in the former articulation and the subsequent development of symptoms in the latter. The trauma occurred while the patient was helping to lift a roll of paper weighing several hundred pounds. The weight slipped and brought sudden strain upon his back. The patient was conscious of a sensation of tearing at the lower part of the spine. The symptoms were those of a sacro-iliac strain with acute tenderness over the synchondrosis and very little tenderness over the lumbosacral joint. He was seen by two surgeons before I examined him, both of whom made a diagnosis of sacro-iliac strain and it was my belief that a sacro-iliac lesion accounted for his symptoms. A fusion of this joint was done and immediate relief of symptoms followed. Three weeks later, the patient was allowed up and was quite comfortable. After his discharge from the hospital at the end of four weeks, pain began to develop in the lumbosacral region. This gradually increased, with extension of the pain along the course of the sciatic nerve. It is assumed that this is a case of severe injury to the sacro-iliac joint and the development of an arthritis in the lumbosacral joint which suffered less injury in the original trauma. The patient was advised that fusion of the lumbosacral joint is indicated but thus far he has refused operation.

Dr. A. Krida—Spina Bifida—Operation and Result.

Dr. Krida showed a two-year-old Italian boy upon whom he had operated for a lumbosacral meningocele when the infant was three months of age. An x-ray demonstrated a perfectly circular tumor which arose from the lumbosacral region by a pedicle about one-half inch in diameter. The only abnormality other than the meningocele which was noted was that the fontanelle appeared somewhat small for the age attained. Operation was done in the head-down position. The sac was completely exposed, then incised. Inspection showed that it was a simple meningocele. This was excised, the stump was closed with two mattress sutures and an inserting stitch. The closure was reenforced by a quadrilateral fascial flap from the lumbar region. Healing *per primum*.

At the time of exhibition of the patient, twenty months after operation, there was no recurrence, nor any abnormality referable to the circulation of the cerebrospinal fluid.

Dr. K. Hansson—Treatment of Calcified Subdeltoid Bursitis.

Many painful shoulders will show some involvement of the subdeltoid or subacromial bursa. This expansion of the synovial membrane of the shoulder joint forms one bursa which lies in part under the acromial process and in part under the deltoid muscle. This explains the double name.

Since 1924, we have treated in this Hospital 224 patients with subacromial bursitis. Ninety-three of these were males and 131 females. All cases were adult patients.

Symptoms may be acute or chronic. Maximum pain and tenderness is found under the acromial process anteriorly and laterally, sometimes over the lower half of the deltoid muscle. Abduction and external and especially internal rotation in the shoulder joint are limited. On passive abduction of the arm to sixty to one hundred and twenty degrees, pressure over the deltoid muscle is lessened.

Symptoms are often unilateral while pathology may be bilateral. The most probable cause of subacromial bursitis is repeated slight trauma to the tendon of the supraspinatus muscle, although disturbance of metabolism and foci of infection, tuberculosis or faulty posture have been put forward as etiological factors.

Pathological examination often shows calcification in or below the bursa. Cultures from the bursa are negative. Histological examination shows tenontitis, necrosis and calcification. The calcification in or about the bursa is usually found in the x-ray if the proper technique is used. Stereoscopic pictures are the most reliable. Differential diagnosis should be made from the periarticular arthritis, neuritis, referred pain from gall bladder and trichiniasis.

Treatment—In acute cases pain is very severe and our first therapeutic step should be to give the patient relief from pain. This is best done by preventing weight-bearing, usually a sling is sufficient. Ultraviolet radiation over the shoulder and upper extremity starting at three minutes and thirty inches and increasing one minute for each daily treatment. The coal-tar preparation luminal or codeine are often necessary to give the patient rest and sleep. As soon as the very acute pain has subsided, usually after three or four days, we start the mobilizing treatment. This consists of external heat applied for ten to twenty minutes over the shoulder affected, followed by diathermy through the bursa for thirty minutes using an amperage that is tolerated by the patient. An important point in the technique is the application of the electrodes. One small electrode should be placed over the bursa and a large one in the axilla or over thorax on the opposite side, or an autocondensation couch may be used as one electrode. This should be followed by gentle massage over the shoulder and whole upper extremity. As pain decreases, exercises should be added. These should be active to begin with, the patient lying on his back to overcome weight-bearing on shoulder joint. Later, passive abduction and external and internal rotation may be added. At this stage it is wise to impress on the patient's mind that part of the restoration is up to him and to give him certain exercises for home use. The average length of this treatment has been one month.

In chronic subacromial bursitis, we have, in addition to the above mentioned pathology, a marked atrophy of the muscles about the shoulder. Therefore, we rely mainly on the static wave and the static spark in these cases and more forceful passive stretchings.

In certain selected cases, operative interference is indicated, especially to prevent recurrence and possibly to shorten the time of disability.

### CLINICAL CONFERENCE OF OCTOBER 28, 1926

Dr. B. Moffat—New Spine Fusion Operation. Exhibition of Cases.

In general the more severe the curve, the greater the necessity for spine fusion. The further the spine deviates from the mid-line, the greater is the moment of the force of gravity acting to increase the curve. The commoner techniques of spine fusion are not applicable to the severe curves. The muscles on the convex side of the curve are so hypertrophied, so taut and so crowded over the spinous processes that this side of the spine is practically inaccessible for fusion.

A check-up by the fluoroscope on those cases in which the commoner methods have been used but applied to the concave side only shows a mobility through the operated area in a large proportion of cases. The technique which I wish to present consists of:

denuding the spinous processes and laminae on the concave side by the Hibbs technique. The first and last spinous processes are split to receive the tibial graft. The intervening processes are broken down. The periosteal flap is then closed over to include the graft. There is then an envelope held out from the spine by the graft like a tent with a ridge pole, in which we have bleeding bone. The space beneath this envelope becomes filled with bone.

The mechanical advantages of this technique I believe to be first: that we have a strut lying in the line of weight-bearing or parallel to it and slightly lateral. The deposition of bone under these circumstances will resist a change of form more stubbornly than a fusion which follows the curve of the spine. Second: The bone deposit is greater in amount the more severe the curve, inasmuch as the space beneath the flap of periosteum will be greater.

The technical advantages of this operation are, first: its simplicity and consequent shortening of time under anaesthesia, second: the lessening of shock to the patient in avoiding any pounding on the spine. The disadvantage of course is that another incision must be made to remove the graft from the tibia.

DR. L. SZERLIP—Exhibition of an Old Intercarpal Dislocation.

Dr. Szerlip presented the case of Frank S., age twenty-nine, painter by occupation. When seen for the first time in the Outpatient Department on September 28, 1926, he stated that on September 2, 1924, while hunting, he fell forty feet from a cliff, landing on his feet and injuring the right wrist and ankle. He thinks that in falling he struck the palmar aspect of the right wrist against a stone. On the day following the accident, without an anaesthetic, the wrist was manipulated and a plaster support applied. One month later the wrist was again manipulated. Since that time treatment has consisted of physiotherapy. The patient has returned to his work as a painter but has not been able to lift heavy objects without assistance. He complains of pain in the wrist and hand, occurring only while working. This pain has diminished considerably and is not very severe at the present time. The hand tires readily.

Examination shows definite atrophy of the forearm to the extent of one-half inch. The right wrist is three-eighths of an inch larger in circumference than the left wrist. Motion at the wrist is accompanied by crepitus. There is an abnormal degree of laxity at the radiocarpal joint, both anteroposteriorly and laterally. There is diminution of grasping power. Pronation and supination are normal. Dorsal flexion is limited at forty-five degrees and palmar flexion at sixty-five degrees. Lateral motions at the wrist are normal. Flexion and extension of the fingers are normal. On the dorsal aspect of the carpus a prominence is palpable. Extreme palmar flexion accentuates this prominence. On extreme palmar flexion a definite depression is seen on the dorsal aspect just distal to the lower end of the radius.

Stereoscopic x-rays in both planes show that the outlines of all of the carpal bones are somewhat irregular. There is some mottling in all the bones, especially in the os magnum, scaphoid and semilunar. The semilunar, scaphoid and trapezoid appear to be in normal alignment with the radius. The pisiform is displaced posteriorly so that it is in the same plane with the semilunar and scaphoid. The os magnum, cuneiform, unciform and trapezium are displaced posteriorly. The second, third and fourth metacarpal bones are also displaced posteriorly and are in alignment with the os magnum and unciform.

This case is presented because of its rarity. Destôt in his book reports only two cases of his own and mentions eight other cases which he has been able to collect from the literature. It is also of interest to note the unusually good function, considering the extent of the injury.

# Current Literature

L'Orthopédie indispensable aux Praticiens. By F. Calot. Neuvieme Édition. Paris, N. Maloine Éditeur, 1926.

The book is divided into five parts:

I. Three preliminary chapters on the general technique.
II. Four chapters on tuberculosis affections.
III. Three chapters on non-tuberculosis affections.
IV. Nine chapters on general affections, some of which require a broader acceptance of the scope of orthopaedic surgery than is recognized in this country by surgeons in general.
V. This part is devoted to the larger problems met with in the diagnosis and treatment of other conditions.

The chapters which deal with plaster technique and with the indications and the technique of puncture and injection of tubercular abscess are of particular value and directions are given with such accuracy that they are useful even to surgeons of experience, because of the practical details, the description of which is ordinarily omitted.

A large part of the book is given to the treatment of tuberculosis of bone and joint diseases of which he has had an abundance of opportunity to observe and treat. These chapters on tuberculosis are thoroughly illustrated and are excellent. He devotes a good deal of space to the method of injection with iodoform paste, etc., a form of treatment which he highly recommends, but which has not met with permanent favor in this country.

The treatment of the affections grouped by Dr. Calot in his work are given in complete detail both in operation and in the mechanical form of apparatus and plaster. The latter forms a large part of his mechanical treatment.

The book, which is an elaboration of the previous editions, contains a great deal of practical value, is profusely and well illustrated.

Études sur les Affections de la Colonne Vertébrale. By André Léri. Paris, Masson et Cie, Éditeurs, 1926.

The author has made a rather unusual, but practical and useful grouping of the affections of the vertebral column, and one which especially lends itself to his treatment of the subjects. The book is divided into five parts in which the following subjects are treated:

1. Anomalies et Troubles du Développement.
2. Affections Traumatiques.
3. Les Maladies Ankylosantes du Rachis.
4. Les Rhumatismes Vertébraux Localisés et leurs Conséquences.
5. Affection Diverses.

The anatomical and pathological features are presented with a thoroughness and completeness that is not often seen, and which adds very materially to the clearness of his treatment in the clinical side of his subjects. Particularly is this so in the first part of the book which is devoted to the consideration of the anomalies of development of the spine. These are divided into the various groups, based on the anatomical variation, and the individual types in each of these groups are dealt with in detail. Particular attention is given to the neurological features in these cases, and their relation to the anatomical anomalies. A short chapter is then given to traumatic affection, and the remainder to the large group of affections more usually placed under the terms of rheumatoid, or of infectious and toxic conditions,—or still more generally, under the general term of Arthritides. One would have wished that he had suggested some method of

grouping based on the etiological factors of these conditions, rather than one so definitely based on the anatomical and pathological features, yet probably this grouping rather than another classification is best suited to the method of his treatment of the subject which is not of the usual way. These chapters as well as that on the anomalies give a clear presentation of the pathological findings, have a particular accuracy of description and show the results of a thorough scientific study and a large experience. The clinical features of the book, including the therapeutics, supplement the other divisions of the work and the portion of each subject dealing with the operative treatment accurately tallies with the preceding anatomical and pathological findings presented. The book must be regarded as one of the outstanding publications on the subjects which it contains.

THE INFLAMMATORY AND TOXIC DISEASES OF BONE. By R. Lawford Knaggs, M.C., F.R.C.S. New York, William Wood & Company, 1926.

The author states in his title that this book is designed as a text book for senior students but he should include among his readers practically all surgeons who are interested in diseases of bones and joints. The author has confined his efforts mainly to the inflammatory diseases of the bone, but he states that he does not make a distinction in this grouping between the infections caused by micro-bacilli, and by toxins. He has also included other diseases of the bones, such as osteo-arthritis, which rightly belongs in this group, as well as osteomalacia, osteitis deformans, ossificans ligamentos, and leontiasis ossea, etc. He has presented his subject in a very comprehensive way from the pathological as well as from the clinical standpoint, and the thoroughness of the treatment of his subjects makes the book particularly valuable to those who wish to study these conditions from the etiological point of view. Although less emphasis is made in proportion on the clinical side, it is by no means neglected and the outlines of treatment which are suggested are sane, and show the results of both study and experience. The illustrations are particularly well selected and are unusually well produced. The book is the outcome of many years of study on the various subjects which have been compiled and elaborated in this volume. There is much of particular value for senior students as is stated in his title, but the value of his book will place his readers over a much wider field.

ORTHOPAEDIC SURGERY. By W. A. Cochrane, M.B., Ch.B., F.R.C.S. (Edinburgh), Assistant Surgeon, The Royal Infirmary, Edinburgh. New York, William Wood & Company, 1926.

The purpose of this book as stated in the preface is "to give the student an understanding of the scope, principles and essential details of the specialty of the Surgery of the Locomotory Apparatus". It is intended to supplement other textbooks and does not aim to give a complete exposition of all the pathologic and clinical features of the conditions considered but rather to point out how much can be done to improve structure and function.

The subject matter is divided in two parts. Part I deals with disabilities of the locomotory apparatus of the body reviewed from the basis of an anatomic and mechanistic conception of disease. Here the author pays tribute to the teachings of Goldthwait and gathers together in a careful and helpful manner the various data, both clinical and experimental, bearing on the relation of physique and correct posture to health and disease. Orthopaedic treatment in the reconstruction of patients with chronic disease is explained in much detail as to rest, support and corrective exercises. Measures of prevention are presented along with treatment. Part II deals with the various types of disability and deformity, presenting them in relation to different anatomic regions rather than as complete disease entities. This method presumes a familiarity on the part of the reader with the fundamental clinical and pathologic features and allows stress to be laid upon the idea of functional restoration and the methods by which this may be accomplished as contrasted with the usual textbook method of emphasizing general therapeutic principles. It is a method which is particularly likely to find favor with the advanced student and busy practitioner.

The anatomic considerations influencing treatment are well brought out, the clinical features of many of the conditions are necessarily sketchy, the recommendations as to therapy are sound and are described in sufficient detail. The approach to the subject is original and the presentation of the postural mechanistic principles of treatment in relation to chronic disease will be found of particular value. The book is written in easy and readable style and is well illustrated. We feel that the writer has seen some real gaps in the usual methods of exposition of the subject of Orthopaedic Surgery and that he has succeeded in satisfactorily closing some of these chinks.

DIFFUSE VERTEBRAL METASTASIS OF PROSTATIC CARCINOMA. Walter M. Simpson. *Am. J. Roentgenol.*, XV, 534, June 1926.

A case is reported which the author says is a "third form of osseous metastasis of prostatic carcinoma, presumably rare, which does not conform to either the common osteoplastic (osteoblastic), or to the less common osteoclastic type" . . . "A case in which a medullary carcinoma of the prostate gland gave no clinical, roentgenographic, or gross anatomical evidence of vertebral metastasis. . . . Subsequent microscopical study of decalcified bone sections from the vertebral bodies revealed generalized vertebral carcinomatosis, without bone destruction or bone proliferation".—*Roades Fayerweather, M.D., Baltimore, Md.*

TRAUMATIC LESIONS OF THE SPINE. W. B. Bowman and L. S. Goin. *Am. J. Roentgenol.*, XVI, 111, Aug. 1926.

The stated purpose of this paper is to describe a large group of congenital anomalies and defects in the spine and their relation to spinal trauma, and to describe the common injuries of the spine and to discuss their differential diagnosis. It is emphasized that congenital anomalies are probably much more frequent than x-ray examination demonstrates. Some of the more serious defects, especially in the fifth lumbar vertebra, in which the neural arches are imperfectly fused are not revealed in radiograms. The instability of a vertebra thus divided is believed by the authors to render it particularly liable to mechanical injury. This is convincingly illustrated in a series of schematic figures. In the same way is shown the greater liability to mechanical injury in partially and in completely sacralized vertebrae. The authors state that in their experience sacro-iliac subluxations do not occur. "We believe that spondylolisthesis is a much more common lesion than it is generally thought to be; that many of them reduce themselves spontaneously, and many cases called sacro-iliac slips are, in reality, cases of unrecognized spondylolisthesis." Stress is laid on the necessity for careful x-ray technique and the inclusion of lateral views. Radiograms are reproduced which show spondylolisthesis in the fourth and in the fifth lumbar vertebrae before and after reduction. A number of other conditions, including spinal fractures, are dealt with. This article is worthy of review by those who have to care for patients with weak or painful backs.—*Roades Fayerweather, M.D., Baltimore, Md.*

THE CORRELATION OF THE ROENTGENOGRAPHIC EVIDENCE WITH THE CLINICAL AND PATHOLOGICAL FACTS IN ACUTE OSTEOMYELITIS. A. O. Wilensky. *Am. J. Roentgenol.*, XVI, 123, Aug. 1926.

The larger part of this article is devoted to outlining the various ways in which the primary focus in the bone may develop, depending upon the circulatory channel through which it is introduced and at what point in that arterial system the infecting organisms are arrested. This matter is presented in an orderly way and with clearness and brevity, aided by illustrations based on Lexer's studies of the circulation in bones. On this basis the author recognizes eight groups of cases, each with a different evolution of the original focus, resulting in more or less distinct clinico-pathological pictures. Noting that the x-ray cannot be relied on for diagnostic purposes in the important early stages of osteomyelitis, he attempts to correlate these several groups with differing types of lesions shown by the x-ray in the succeeding stages of their evolution. The author's presentation is so condensed that an abstract describing the characteristics of the different groups would require the inclusion of a large part of the original paper. This study

contains suggestio ns of practical value to the bone surgeon.—*Roades Fayerweather, M.D., Baltimore, Md.*

CLINICAL AND EXPERIMENTAL CONTRIBUTION TO THE STUDY OF LOCALIZED AND GENERALIZED OSTEITIS FIBROSA. Felix Mandl. *Arch. f. klin. Chir.*, CXLIII, 1, 1926.

The author differentiates between Paget's osteitis deformans and osteitis fibrosa first described by Von Recklinghausen. Paget's disease begins in later life, usually between the fifth and sixth decade; the onset is painless. As a rule the flat bones are first involved and show the pathological changes more definitely than the long bones. X-ray shows marked thickening of the cortex. In osteitis fibrosa the onset is usually earlier in life. In the generalized form of the disease it is associated with marked pain, with spontaneous fractures and with the formation of cysts in the bone. It is a progressive condition. Microscopically osteitis deformans and osteitis fibrosa cannot be sharply differentiated from one another.

The author then emphasizes (and this is the purpose of the paper) the difference between the localized osteitis fibrosa and the generalized form. Until recently these two have been accepted as manifestations of the same disease. Konjetzny was the first to point out the dissimilarity between the localized and generalized form. Mandl sustains his view. He emphasizes that etiologically the localized form is almost always the result of a local trauma, and that the generalized has nothing to do with trauma and seems on the other hand to be a systemic disease closely related to rickets and osteomalacia. It probably is due to some dysfunction of the parathyroids.

Clinically:—The local form gives, with rare exceptions, no symptoms until the bone fractures after comparatively slight trauma. The generalized form, however, begins with severe general pain, usually characterized as rheumatic, followed by increasing deformity of the bones. It occurs in older individuals than the localized form and the prognosis is bad.

Therapaeutically:—The localized form can be easily cured by operation (either excision or, where cysts have formed, by curetting the cysts). The general form, however, has thus far not been amenable to any form of therapy. Mandl thinks that the term "generalized osteitis fibrosa" should be applied whenever more than one bone is involved or where a single bone shows multiple discrete foci. The article is enriched by detailed case reports telling of the successful operative results in cases of localized osteitis fibrosa in the Vienna clinic by Prof. Hochenegg.

A second paper dealing with the generalized form of osteitis fibrosa is to follow this first article.—*Leo Mayer, M.D., New York, N.Y.*

FRACTURE OF THE VERTEBRA AFTER MILD TRAUMATA. Puschel. *Arch. f. klin. Chir.*, CXLIII, 78, 1926.

Puschel reports fourteen cases of fracture of the vertebrae subsequent to comparatively mild injuries such as a fall of a distance of two or three feet, slipping down the stairs, etc. In about half of the cases kyphos developed. The paper is written from the point of view of the roentgenologist and does not consider the therapy. The author emphasizes the well known fact that there is a striking variation in the symptoms produced by what in the x-ray picture would seem to be the same type of fracture.—*Leo Mayer, M.D., New York, N. Y.*

ROENTGEN THERAPY OF METASTATIC BONE TUMORS. Borak. *Arch. f. klin. Chir.*, CXLIII, 185, 1926.

This paper deals with what has heretofore been considered a hopeless condition, namely, malignant metastases of the bone subsequent to operative removal of primary foci. Borak's paper is of value since it shows that although the ultimate prognosis in these cases is poor, much can be done to relieve suffering by x-ray treatment directed to the bone metastasis. He stresses two significant facts: first, that this type of bone metastasis is particularly susceptible to x-ray influence; second, that very frequently there are no metastases other than those found in the bone and that these bone foci may for a number of years constitute the only symptoms of malignant disease. He cites

cases of carcinomatous metastases of the spine suffering severe pain, who, subsequent to x-ray therapy, were relieved of all subjective symptoms and lived in comfort for two and a half years. For details of the dosage the reader should consult the original paper. These facts coming from as reliable a clinic as Holzknecht's in Vienna have more than a passing significance.—*Leo Mayer, M.D., New York, N. Y.*

BRITTLE BONES AND BLUE SCLERA. J. Albert Key. *Arch. Surg.*, XIII, 523, Oct. 1926.

Various types of abnormal fragility of the bones have been grouped together under the term "fragilitas ossium". Analysis of the cases reported in the literature leads the author to the following classification:

1. Hereditary form: Hereditary hypoplasia of the mesenchyme.
2. Non-hereditary forms: (a) Osteogenesis imperfecta; (b) osteopsathyrosis with white sclera; (c) osteopsathyrosis with blue sclera.
3. Probably not hereditary: Osteosclerosis fragilis generalisata, or marble bones.

The author has made a careful clinical, roentgenological, and pathological study of one patient of the hereditary form and has made a detailed comparison of the characteristics shown by his patient with those previously reported. His studies lead him to the conclusions that the disease is a developmental anomaly of the hypoplasia of the mesenchyme, transmitted as a hereditary characteristic by either of the parents, from generation to generation. Fragility of the bones is only one factor of a syndrome which includes short stature, hypermobility of the joints, deafness, and blue sclera. The last of these, the blue sclera, is the dominant characteristic and is the one feature invariably shown by patients with hereditary hypoplasia of the mesenchyme.—*I. Wm. Nachlas, M.D., Baltimore, Md.*

THE USE OF FASCIA FOR THE REENFORCEMENT OF RELAXED JOINTS. George E. Bennett. *Arch. Surg.*, XIII, 655, Nov. 1926.

This article is essentially a report of two new operative procedures, each designed to offer a simple correction for a hitherto annoying and not uncommon ailment. One operation aims to correct the disability that results from a rupture of the anterior crucial ligament with relaxation of the knee joint,—the joint that permits the normal functions of civil life but interferes with active participation in athletic pursuits.

The operation consists of application of the capsule and fascia just medial to the patella in such fashion that the layers overlap to form a strong anteromedial ligament. In addition to this, a reenforcement is offered by the introduction of a fascial strip running from the medial condyle toward the tuberosity of the tibia.

Six cases are reported, of which five are described as unqualified successes. The activities which the patients undertook postoperatively are ample test of the serviceability of this operation.

The second operation described is designed to combat the recurrent dislocation of the shoulder. It consists of lacing the relaxed or torn anterior capsule of the shoulder with a strip of fascia lata which also passes through the acromion process and acts as a check ligament. The operation is characterized by its simplicity and, judging from the cases reported, by its efficiency.

The operations are grouped together on the basis of their common factor, the use of the fascia lata as a reenforcing material.

Excellent drawings facilitate the visualization of the operative procedures step by step.—*I. Wm. Nachlas, M.D., Baltimore, Md.*

THE RELATIONSHIP BETWEEN VERTEBRAL EPIPHYSITIS AND SPINAL DEFORMITY. Joseph Buchman. *Arch. Surg.*, XIII, 568, Oct. 1926.

To combat the theories that vertebral epiphysitis is the result of spinal deformity, rather than an etiological factor in the production of such deformity, Buchman offers two case reports.

The two patients whose histories are presented were originally studied as normal individuals. Their posture was normal. X-rays of their spines, however, showed the changes characteristic of vertebral epiphysitis. Subsequent examinations showed a

# Annual Meeting

*of the*

## AMERICAN ORTHOPAEDIC ASSOCIATION

The forty-first Annual Meeting of the American Orthopaedic Association will be held in the Yosemite Valley on June 13, 14, 15 and 16, 1927. This will be the first meeting of the Association on the Pacific Coast and the President, Dr. James T. Watkins, with the aid of the San Francisco and Los Angeles Orthopaedic Clubs, is making special provision for the presentation of the surgical program and for the social entertainment of the members and guests.

It is planned to have an "Orthopaedic Special" over the Santa Fe, which will leave Boston June 4, and arrive at Los Angeles June 10, via Chicago, Kansas City, Albuquerque, providing opportunity to visit these places and also the Grand Canyon. There will be entertainment at Los Angeles on Friday evening, June 10, and on Saturday there will be a clinical day provided by the Los Angeles Club. The train will leave Saturday evening for the Yosemite Valley arriving Sunday noon. The scientific meeting will take place in the Yosemite Valley on Monday, Tuesday and Thursday, June 13, 14, and 16. On Wednesday, June 15, there will be an opportunity for the members and guests to visit the points of interest in the surrounding country. Friday, June 17, the meeting will adjourn to San Francisco and will be the guests of the San Francisco Club. A clinical day will be arranged for Saturday, June 18.

Provision will be made for the attending members and guests to make excursions to the points of interest in the West and return to the East by whatever route may be desired. It is requested by the Committee that all who may plan to attend this meeting notify as early as possible the President, Dr. James T. Watkins, Medical Building, Hyde and Bush Streets, San Francisco, California, in order that the Committee may plan in general for the number for which it may be necessary to provide. For further information in regard to arrangements for attending the meeting, write to President Dr. James T. Watkins.

As this is the first meeting to be held on the Pacific Coast, it is requested that as many members and guests as possible plan to be present and to make this Annual Meeting an unusual success.

This preliminary notice is given in order that those intending to take part in this meeting may be acquainted with the general plan and the dates of the meeting. The complete announcement of the scientific program and of the arrangements made for the entertainment of the guests will be made in the April number of the *Journal*.

JANUARY 1927.

development of postural difficulty. The author postulates that since in these cases the epiphysitis involvement antedated the bony deformity one cannot say that the bone disease was the result of the deformity, but rather the cause thereof. He also presents the fact that in such deformities as one sees in rickets, torticollis, and Pott's disease, one finds no vertebral epiphysitis. He deduces that vertebral epiphysitis is a "competent cause of spinal deformity".—*I. Wm. Nachlas, M.D., Baltimore, Md.*

CABOT CASE RECORD FROM THE MASS. GEN. HOSPITAL. An Epoch-Making Case of Fractured Hip (Intratrochanteric Fracture). *Boston Med. and Surg. J.*, CXCV, 549, Sept. 9, 1926.

A most interesting case report of an intratrochanteric fracture of the femur appears in the Boston Medical and Surgical Journal for Sept. 9, 1926. The patient, a woman aged sixty-five, had been treated at the Mass. Gen. Hospital Diabetic Clinic for four years. She entered the last time on Jan. 11, 1926 with severe pain, swelling and angulation of the left femur after a fall. X-ray revealed a comminuted intratrochanteric fracture with some displacement and angulation. Under treatment in abduction Thomas splint, radiograms on Feb. 18 showed fairly good alignment. Her course in the hospital was a stormy one, including an hypoglycaemic reaction, dorsal decubitus, and later, coma. Traction was removed from the leg on Feb. 20. On March 4, the patient died, seven weeks after her fall, with a diagnosis of diabetes mellitus, arteriosclerosis, and fractured femur, all confirmed by postmortem examination. Following is the clinical necropsy report of Dr. Henry Marble concerning the femur: "This bone shows an intratrochanteric fracture which is solid. This is a seven weeks old fracture. It has changed our conception of things. We used to keep intratrochanteric fractures up for twelve weeks; now we let them down in six. *The poorest possible risk unites an intratrochanteric fracture, we know, in seven weeks.*" This necropsy has established a new principle as to the time of keeping this type of fracture in apparatus.—*Henry W. Lamb, M.D., Portland, Maine.*

THE DIAGNOSTIC SIGNIFICANCE OF LATERAL CURVATURE OF THE SPINE CAUSED BY MUSCULAR SPASM. John Russel Carty. *Boston Med. and Surg. J.*, CXCV, 654, Sept. 30, 1926.

The author discusses briefly the type of scoliosis due to reflex spasm of groups of spinal muscles, evaluating their diagnostic significance in obscure renal and pathological conditions. The spasmodic curve is generally single, and what is most important, the convexity points away from the affected side. If the underlying pathological condition is one of recent acquirement the deformity is usually limited to one region; but if of long standing, a readjustment of equilibrium of the entire spine naturally takes place. Of the six conditions [(1) trauma to spinal muscles, (2) infection of spinal muscles, (3) pleural effusion, (4) renal stone, (5) hydronephrosis, (6) perinephritic abscess] with which spasmodic scoliosis is to be associated, the author treats of only the first four, giving an illustrative case of each. In a radiographic study of early empyema in children, the writer found that 78% of those having pleural effusion, showed a thoracic scoliosis. With large renal stones, the deformity was found in sixty of one hundred cases. In the case illustrative of this, at x-ray examination of the heart, the lumbodorsal scoliosis was noted, and, because of this, studies were made of both kidneys, a stone in a hydronephritic kidney being revealed.

This brief article holds a suggestion worth remembering in obscure cases, particularly to the orthopaedic surgeon who is so much more apt to see scoliosis either mild or severe, in which the etiology is not definitely established.—*Henry W. Lamb, M.D., Portland, Maine.*

SCOLIOSIS DUE TO UNILATERAL MUSCULAR SPASM. P. Jenner Verrall. *Brit. Med. J.*, 481, Sept. 11, 1926.

Mr. Verrall reports a case of unilateral muscular spasm of the erector spinae muscles, which began as lumbago and became more acute, until in about ten days the patient developed a bilateral sciatica. The pain was worse on walking, but wore off during the

day. She was subjected to the usual treatment, including complete rest in bed, but without any benefit.

After a year of treatment she was seen and the condition at that time was as follows:

The pain and acute spasm was localized to the right erector spinae. Between the mid-dorsal and mid-lumbar region, there was continuous spasm, standing out in a hard mass and the spine was held convex to the left with corresponding tilting of the pelvis. There was no spasm of the abdominal muscles.

Under general anaesthetic, the spine was manipulated, and many adhesions were felt and heard to give way. After this mobilization, the spasm disappeared.

X-rays in this case were consistently negative.

This case never suggested a diagnosis of hysteria, and was unlike hysterical curvatures and tilted pelvises which are so frequently seen.

It was obvious that there was an irritative lesion of the nerves supplying the affected muscles.—*N. T. Williamson, M.D., Montreal.*

TREATMENT OF GOUT. George Graham. *Brit. Med. J.*, Oct. 16, 1926.

Dr. Graham refuted the impression that gout was a rare disease, and he stated that it still occurs rather frequently. In obscure cases, the family history is of great value in the diagnosis.

The estimate of uric acid in the blood is sometimes of assistance in doubtful cases. The high figure for the blood uric acid above 3 mg. per 100 c.c. was in favor of gout, still the low one did not negative the diagnosis.

The first essential in treatment of an acute attack was rest to the part. Colchicum was the best drug in this acute stage. It did not affect the excretion of uric acid, but relieved the pain and cut short the attack. In preventing an attack, diet played a great part. The most important thing was abstinence from foods containing a large amount of neucleoproteins. Alcohol in certain forms was a contributory cause. The drug which was of most value was cinchophen, sold under numerous names (atophan, agotan, phenoquin and quinophan). Dr. Graham suggested that it was only necessary to give the drug for three days and then allow a period of rest with no drugs. He has adopted this principle. One patient had a cinchopen preparation for six and one-half years in twenty gr. doses three times a day for three consecutive days of each week. He had constant improvement.

Dr. Graham was also of the opinion that cinchophen is useful in cases of acute rheumatism or other acute conditions. The after effects were not serious.

He stresses the point that this drug should be given for not more than three consecutive days, when the patient should be given a rest.—*N. T. Williamson, M.D., Montreal.*

DERANGEMENT OF THE ANKLE JOINT FOLLOWING FRACTURES OF THE LOWER END OF THE TIBIA AND FIBULA. Lionel D. Prince. *Calif. and West. Med.*, XXV, 42, July 1926.

The disabilities mentioned in the title are usually due to disturbance of the weight-bearing line at the ankle joint as a result of tilting at the astragalus and the lower articular surface of the tibia.

The astragalus being closely fitted in between the internal and external malleoli as though in a mortise, it becomes unstable if this mortise is widened by fracture.

Such fractures are very common and are usually the result of indirect violence. The foot is twisted inward or outward causing breaking of the outer malleolus first, then, if force is sufficient, the inner malleolus. Another mechanism is forcible plantar flexion of the entire foot which causes a fracture of the posterior margin of the tibial articular surface.

Complete anatomical replacement of fragments with careful after-treatment is essential to good function. This can usually be accomplished by closed reduction. Unless the skin shows blebs, or unless there is unusual swelling, the fracture should be reduced without delay. Complete relaxation should be obtained with general anaesthetic.

It is a good plan in doing the reduction to keep in mind the motions the foot went through when the fracture occurred and to attempt to reverse these motions. The foot must be fixed in eversion by plaster cast or other rigid support.

After three or four weeks the cast is split and physiotherapy started. Weight-bearing should not begin until six weeks and then cautiously with a shoe built up one-fourth inch on the inner edge of heel and sole.

Subsequent disabilities may be limitation of anteroposterior motion due to minor joint changes or to a shortened heel cord. Diminished or painful lateral motion may also occur. Proper physiotherapy should preclude these disabilities.

In case already united with deformity the author does double cuneifom osteotomy just above the fracture site and corrects the alignment.

Four illustrative cases, in which osteotomy for correction was done, are reported in detail.—*William Arthur Clark, M.D., Pasadena, California.*

Chronic Arthritis: Its Treatment with Emetin. Leonard W. Ely. *Calif. and West. Med.*, XXV, 625, Nov. 1926.

Although admitting that the amoeba theory as a cause of arthritis has not been proven, the author holds that the areas of aseptic necrosis in the bone and reaction of the marrow around them indicate the presence of some living organism, the changes one would expect from protozoa.

He does not accept the idea of infection as an etiologic factor.

The routine treatment of chronic arthritis as carried out by the author is as follows: Emetin hydrochloride 0.065 intravenous daily for twelve days, followed by emetin bismuth iodide daily for six days. Neoarsphenamin weekly for three doses 0.45, 0.6 and 0.9 respectively. The neoarsphenamin is omitted in cases where no protozoa are found in the stools.

Nausea, diarrhea, increase in pulse rate and fall in blood pressure are all indications for discontinuance of emetin, temporarily at least. Muscular weakness is a frequent symptom following emetin and, if in a severe degree, the emetin should be stopped.

Although a dangerous drug, affecting the heart, intestines and muscles, emetin, when cautiously and intelligently used, has a distinct value in treatment of chronic arthritis.

A synopsis of eighty-six cases is given, showing cures in two cases, improvement of all degrees in forty-six, no improvement in sixteen and treatment stopped in twelve.—*William Arthur Clark, M.D., Pasadena, California.*

Acute Arthritis. A. Gibson. *Can. Med. Assn. J.*, XVI, 1033, Sept. 1926.

The paper is confined to the subject of acute arthritis. The surgical anatomy of the joint is dealt with first of all and it is pointed out that in every case the synovial membrane is affected. If the case be efficiently treated at an early stage the synovial membrane alone may bear the brunt of the fight. Experimental work on acute arthritis is reviewed. It has been shown that acute arthritis is more readily produced in joints already sensitized by the toxins of the streptococcus. The bearing of this observation upon the influence of focal infections is manifest.

The process may end in complete resolution, complete ankylosis, fibrous or bony, or it may become subacute or chronic. These are the cases which form a standing reproach to the profession. It is pointed out that in many cases the removal of recognized foci of infection merely means the locking of the stable door after the steed has vanished. The lymphatic glands may prove to be a lurking place for the responsible organisms. There is much work to be done along this line.

Of the various types of infection, the gonorrhoeal, the pneumococcal, streptococcal and staphylococcal are considered in detail.

In regard to treatment, aspiration of the joint with bacterial and cytological investigation of the fluid is a necessary preliminary. Accurate judgment is necessary to determine the relative importance of rest and movement. Painless movement is always useful. If possible, the pathological process should be limited to the synovial membrane.

To accomplish this it may be sufficient to aspirate the joint, or it may be better to wash out the joint thoroughly as recommended by Cotton. The Willems method is then described.

The injection of strong antiseptic into a joint is looked on with disfavor. The use of mercurochrome or gentian violet is not likely to bring about dramatic results.—*Alexander Gibson, F.R.C.S., Winnipeg.*

RESUMÉ ON THE TREATMENT OF FRACTURES. Presenting the Views of the Academy of Medicine of Western Ontario. Geo. A. Ramsay, *Can. Med. Assn. J.*, XVI, 1083, Sept. 1926.

Fractures in the great majority of cases are within the scope of the general practitioner, hence the standard of results will follow from the technique that is possible for the man in general practice.

Reduction of displacement should be brought about under the best possible conditions of anaesthesia and assistance. The position should be maintained by one or all of the principles of traction, coaptation and suspension. In the femur this is secured by the Thomas splint with extension; in the leg by plaster casings. In the upper limb, the Jones humerus splint or the aeroplane splint is advisable. The forearm lends itself to anterior and posterior splints of plaster. The clavicle responds well to the clavicular cross. Vertical suspension aids lymphatic and venous drainage and adds to the comfort of the patient.

The nearer the joint, the sooner you move.

The larger the bone, the longer you splint.

Massage from the beginning.

Protected active movement may begin as soon as pain will permit. Good anatomical restitution produces best and quickest functional results. Fractures should be reduced as soon as possible after receipt of injury. The results are best and worst at the extremes of age.

Fractures of the femur require separate weight and pulley for each adhesive strip. In children vertical extension of both legs is used. Bromides for ten days will keep the patient in a restful mood.

Operative treatment is the preferable method in any fracture which cannot be properly reduced or satisfactorily retained after reduction. The benefits to be expected are bony union, a straight bone, good function and the minimum use of rigid splints. The dangers are infection and possible refracture of the bone due to osteoporosis.

In long-standing cases of non-union operation is rarely indicated as the function is not likely to be enhanced by operative fixation.—*Alexander Gibson, F.R.C.S., Winnipeg.*

THE INFECTIVE ARTHRITIDES. ON A POSSIBLE RELATIONSHIP BETWEEN HYPOPARATHYROIDISM AND THE CHRONIC ARTHRITIDES. A. Mackenzie Forbes. *Can. Med. Assn. J.*, XVI, 1232, Oct. 1926.

The opinion has been reiterated by the author that the arthritides are essentially due to infection. Yet it is difficult or impossible to state what is the infecting organism. During the last few years, insistence has been laid on three coincident changes. (1) in joints, (2) in parathyroid glands, (3) in intestinal mucosa. Macullum's work has indeed suggested that changes in the cells of the intestinal mucosa may furnish a portal of infection. An article by Collip is referred to in which it is said that "a state of hypoparathyroidism may exist". For this reason Forbes includes a preparation of parathyroid in "the therapeutic armamentarium". For centuries meat has been looked upon as diet unsuitable for arthritis, and laboratory experiments have shown that meat "aggravates symptoms in parathyroidectomized animals". In the author's opinion about ninety per cent. of chronic arthritides owe their origin to changes in the intestine.—*Alexander Gibson, F.R.C.S., Winnipeg.*

FIBROSITIS (MYALGIA, CHRONIC MUSCULAR RHEUMATISM). Chas. Hunter. *Can. Med. Assn. J.*, XVI, 1319, Nov. 1926.

*Etiology.* Many date the onset from some particular muscle strain, in others chilling of the body precedes an attack. The influence of infection is undoubted. In run

down conditions muscular pains often appear which vanish with improvement of the general health.

*Symptoms.* The outstanding symptom is pain referred to muscles or tendinous insertions; the pain is present only when the affected muscle is thrown into action, and disappears on relaxation; the muscle is sensitive to direct palpation. In chronic cases, circumscribed thickenings may sometimes be palpated and are exquisitely sensitive.

The exact pathological nature of these nodules is a matter of dispute; they may be a true fibrositis, or a disturbance of the colloid constituents of muscular tissue, or a neuralgia of the sensory nerves in muscle.

In diagnosis a broad survey must be made for orthopaedic faults, while teeth, tonsils, sinuses, urethra and prostate must be examined. Torticollis, pleurodynia and lumbago should not be diagnosed without excluding other conditions. Gluteal myalgia is often diagnosed as sciatica. It may be acute and completely disabling or may be associated with aching and stiffness. Myalgia of the calf muscles must be distinguished from phlebitis and from peripheral neuritis. Occipital myalgia—the so called "rheumatic headache"—is seldom recognized. Brachial myalgia and myalgia of the abdominal muscles are frequently associated with trauma or strain.

*Treatment.* We must consider the individual generally; his mode of life, his state of nutrition, his occupation, etc. Games and exercises should be encouraged. Foci of infection should be removed. For chronic myalgia and even for subacute myalgia the sovereign remedy is massage. General massage is useless. Firm massage with the tips of the fingers combined later with friction and kneading is necessary to prevent recurrences. Usually the pain is lessened after a few treatments, but often persistent treatment for weeks is necessary to be of permanent value. Normal saline injections may be of some value, or novocaine ½% in 5 to 10 c.c. doses may be employed. Diathermy or quartz lamp is of secondary value. In refractory cases, the patient becomes discouraged and neurasthenic so that psychotherapy must be combined with physiotherapy.—*Alexander Gibson, F.R.C.S., Winnipeg.*

Occupational Therapy. Goldwin W. Howland. *Can. Med. Assn. J.*, XVI, 1324, Nov. 1926.

Occupational therapy may be made use of entirely as a plan of treatment without thought of financial return, the work being destroyed when made, only to be remade. Sometimes it is found that the interest of the patient is increased, and the work bettered if the product is permitted to be sold.

"Sheltered employment" includes work done by men who are unable to follow their former employment. They are given work for a definite number of hours, and are paid at fixed rates. The workshops for the blind fall under this category, and in some cities there are workshops for the aged and infirm.

"Vocational rehabilitation" means that men who are unable to go back to their old occupation are taught absolutely new work by which it is hoped they may be able finally to provide for themselves and their families.

Occupational therapy may be general or special. In the former case large groups of patients may have to be treated by one aide. In the specialized form the work is definitely arranged to suit the individual patient. A large field for this is found in mental hospitals. Nervous and cardiac cases are also benefited.

In the surgical field, it has been found that employment of an injured limb in some type of work which insures movement not two or three times a day, but possibly thousands of times in two or three hours' work, is much superior to massage and other treatments. The Workmen's Compensation Board of Ontario is definitely in favor of this type of treatment. In some cases the large insurance companies are supporting the work to a large extent.

The different types of occupation are numerous. Simple basketry, raffia work, hand-loom weaving in which rugs, silk scarfs, even complete dresses are turned out, are best seen in the school at Boston. Metal work in brass and copper is well done in Toronto. Wood-carving, pottery, the making of jewelry, batik, book-binding, cement work, cord work, design, stenciling and toy-making, form part of the course which the

aides are taught. Artistic leather work is a specially attractive form of occupational therapy.

The two most prominent schools are those of Boston and Philadelphia. The time occupied in the course is about twelve to fifteen months. The work has been advancing in Canada for about four years, and it is felt that a great future is before it.—*Alexander Gibson, F.R.C.S., Winnipeg.*

TREATMENT OF ACUTE HEMATOGENOUS INFECTIOUS OSTEOMYELITIS. T. Krasnobaew. *Chir. d. org. di movimento*, X, 6, 537, July 1926.

Based upon the author's experience of 600 cases of which 428 were acute osteomyelitis, as well as upon the analysis of reports in the literature, especially upon the large series of Clemm, and that of Bruns' clinic in Tuebingen, the latter with over 1000 cases. In the author's series of 428 cases, 96 died or 22%. Clemm's series of 67 deaths in 320 cases amounts to 21%.

Discussing the plans and details of the treatment, the author begins with the involvement of femur and tibia. As soon as diagnosis is made and before any fluctuation appears, incision is made under ethylchloride anaesthesia through entire thickness of soft tissues into the periosteum. This is especially necessary in severe cases, when life is in the balance. Serosanguineous fluid, but no pus is encountered. Incisions are moderately long, 5 to 6 cm. For the last ten years the author has used neither drain tubes nor packing. When the abscess is deeply situated, counter incisions are made. This is the treatment until disappearance of fever and septicemia. Only in rare cases of osteomyelitis of the tibia, when the entire bone is involved and bathed in pus, the latter is removed. If the infection extends into the joint, simple puncture in milder, and arthrotomy in severer cases is indicated; no lavage of the joint but aseptic treatment. The more one spares the tissues and refrains from tubes and packings, the less frequently arthrotomy will become necessary. In 145 cases of osteomyelitis of both femur and tibia, including the femoral neck, arthrotomy was done only ten times: 3 hips, with 2 deaths, 5 knees with 2 deaths and 2 ankles with 1 death. Author's results: of 145 patients with osteomyelitis of femur and tibia, 48 deaths or 33%.

The osteomyelitis of the neck of femur deserves special discussion. Neck of femur as well as the upper epiphysis are often the seat of osteomyelitis infection, characterized by absence of suppuration. These are treated conservatively with plaster.

Under this form of treatment the author did not have to resort to removal of the diaphysis in the last three or four years.

Following the acute stage one awaits the formation of the involucrum, that is, three or four months before sequestrotomy. This is done with greatest conservatism, removing only the manifestly necrotic bone and leaving suspected tissue intact. The wound is closed, after cleansing and iodoform treatment by suture in layers. Sinuses are curetted.

Acute osteomyelitis of the os ilii is treated in the same manner. The author reports 20 cases with 8 deaths. Owing to the complex anatomical relations between os ilii and the surrounding soft structures, it is impossible to procure adequate drainage except by resection of a considerable portion of the bone.

In the acute osteomyelitis of the scapula the results were excellent: recovery in all 17 cases, in 16 after simple incision.

The bodies of the vertebrae are fortunately rarely involved in acute osteomyelitis. The outcome is usually fatal and the diagnosis made postmortem. Involvement of the transverse processes and of the spines is likewise rare. Abscesses form toward the long muscles of the back and drainage results usually in recovery.

Epiphyseal osteomyelitis: primary infection of the epiphyseal bone nucleus in the long bones and subsequent involvement of the adjacent joint. Here belong the great majority of cases of primary suppurative arthritis in children of the first two years. The author follows the general principles of treatment of acute osteomyelitis: If the pus is contained within the joint (empyema), puncture every three or four days; if it has penetrated the joint, arthrotomy and a series of incisions into the soft part for drainage.

The result for the different articulations was as follows:

| | | |
|---|---|---|
| Hip joint, | 69 cases, | 16 deaths, 23% |
| Knee, | 35 cases, | 2 deaths, 8% |
| Shoulder | 10 cases, | 2 deaths |
| Ankle | 9 cases, | 0 deaths, |
| Elbow, | 2 cases, | 1 death |
| Wrist, | 1 case | 0 death |

The author arrives at the following conclusions:

The general condition of the patient is above all to be respected. In severe cases, all more or less extensive operative plans must be avoided. In early stage, one must be content with evacuation. Later the treatment of the cellulitis demands full attention. No packs and sponges: drainage tubes rarely and for short time only. If the wounds are properly managed, amputation or exarticulation will very seldom be necessary.

At the end of the septic stage, without waiting for completion of the involucrum, a sequestrotomy is done in which only the manifestly necrotic portions are removed. Too much interference in epiphyseal osteomyelitis with joint involvement is deleterious. In empyema of the joint, puncture suffices; in severer cases with perforation of the joint capsule, arthrotomy and incisions into the soft parts is indicated. Resections are only necessary in osteomyelitis of the femoral epiphysis, and then only in the rare cases in which there is necrosis of the whole epiphysis and its separation from the shaft.—*A. Steindler, Iowa City.*

Chronic Tuberculous Hygroma, Secondary to Trauma (Bursa ischiatica posterior or gluteotuberosa, and bursa trochanterica profunda). G. Forni. *Chir. d. org. di movimento*, X, 6, 554, July 1926.

The author reports two cases of subgluteal hygroma cured by operation. In the first case the histological findings proved the tuberculous nature of the lesion, notwithstanding the fact that typical tubercles were absent and that the bacteriological findings were negative. The structure of the walls was analogous to that of tuberculogenetic membranes except for the absence of true tubercles and of signs of calcification.

In the other case the picture was that of a subacute inflammatory process with hemorrhages following the rupture of capillary vessels, also probably of tuberculous nature.

In both instances the importance of a trauma in the etiology of the condition was undeniable from the history, causing the primary extravasation of blood found in the bursa. The hemorrhage led to chronic inflammatory changes in the bursal wall to which secondarily tuberculous infection was added. In the first case there was a serofibrinous, in the second a hemorrhagic exudate.

Both cases serve as illustrations of the importance of trauma in the occurrence of an inflammatory chronic, exudative and neoformative process of tuberculous nature with conspicuous signs of necrobiotic changes of the new formed tissue.—*A. Steindler, Iowa City, Ia.*

Scapulopexy in a Case of Progressive Muscular Dystrophy. S. Marconi. *Chir. d. org. di movimento*, X, 6, 569, July 1926.

Report of a case of progressive muscular dystrophy of the Landouzy-Dejerine type in a boy of twelve, with atrophy of the supra and infra spinous muscles, the rhomboids and the trapezius. The arm could not be elevated higher than 45 to 50 degrees.

Relative to the operative treatment of this condition, Putti reported two cases operated on by Eiselberg in which an interscapular osteodesis was performed, as well as a case of Codivilla's of the same type, operated with good result. Perthes transposed the levator anguli scapulae from the superior internal to the superior external angle of the scapula, Eden part of the rhomboids and the levator and Katzenstein part of the latissimus dorsi and of the trapezius of the other side, all in cases of paralysis of the trapezius. Ombrédanne fixes the supero-internal angle of the scapula to the transverse processes with wire, while Rothchild, in a case of isolated paralysis of the trapezius from injury to the accessory nerve, anchored the supero-internal angle of the scapula

to the deep musculature of the back, by means of a long fascia flap sutured under strong tension from the lumbar musculature to the angle of the shoulder blade. Lange unites the supero-internal angle to the spinous processes of the lower cervical vertebrae with strong silk sutures.

In his case, the author used the following technique: The incision was made from the first dorsal spinous process horizontally to the upper inner angle of the scapula, then downward half-way to the vertebral border. This border is dissected and the rhomboids as well as all other muscles are detached from it. A hole is drilled into the upper inner angle. Then the spinous process of the first dorsal is likewise denuded and a hole is drilled at its base. A double silver wire is then run through the holes and tied under strong tension, while the scapula is held in correct position, i.e. approached to the median line. The rhomboid is reefed by sutures.

The immediate result was very good. Both scapulae were at the same level and the arm could be raised actively to the horizontal. Three months later the result was maintained; abduction was complete; the scapula was possibly a little lower.—*A. Steindler, Iowa City, Ia.*

Two Cases of Pathological Subluxation of the Sacro-iliac Articulation. A. Mezzari. *Chir. d. org. di movimento*, X, 6, 605, July 1926.

Valtancoli, who in 1921 published the statistics on vertebral tuberculosis of the Istituto Rizzoli, records 31 cases of sacro-iliac tuberculosis among 1271 cases of tuberculosis of the spine. In the author's series there were 24 cases of sacro-iliac tuberculosis observed since 1919. Of these, 2 cases showed pathological subluxation of the sacro-iliac joint. One case died and came to autopsy. In the second case the clinical examination led one to suspect a disalignment between sacrum and os ilii and this was shown clearly in the x-ray. In the first case autopsy showed that the lower end of the articular joint surface was gaping, that the os ilii had migrated upward and had rotated internally. The transverse process of the fifth lumbar was about 1 cm. below the upper iliac margin, while on the other side it was at the same level with the posterior iliac spine. The sacro-iliac articulation in its remaining portion was ankylosed.—*A. Steindler, Iowa City, Ia.*

Contribution to the Radiological Study of Congenital Anomalies of the Spine. F. Perussia. *Chir. d. org. di movimento*, X, 6, 614, July 1926.

X-ray examination of a twelve year old girl with no particular symptoms of the spine except a certain tenderness along the spinal column, showed the following anomalies: There were eleven dorsal and six lumbar segments. The study of the single vertebra showed a partial sagittal cleft of the seventh dorsal, an irregularity in the outlines of the following vertebrae and a flattening of the bodies of the eleventh and twelfth, the latter showing the characters of a lumbar segment without ribs. In the region of the tenth to the twelfth dorsal vertebrae there was a rachischisis. There was furthermore a synostosis between the twelfth dorsal and the first lumbar vertebrae. The case is of interest because of the multiplicity of anomalies which harmonizes with the theory of Putti of the endogenic or intrinsic rather than the exogenic pathogenesis from external mechanical factors. It also confirms Putti's theory of the connection between flatness of the vertebrae and rachischisis and finally the contention of Bertolotti, regarding the frequent association of anomalies in differentiation with grave and various developmental errors such as rachischisis and vertebral fusion.

From a practical point of view the case shows that even grave anomalies may remain entirely latent clinically, and that in radiological examinations of the infantile spine, great attention must be paid to the study of the spine as a whole, in order to avoid erroneous conclusions from such findings as vertebral fusion. In this case this might have made the impression of Pott's disease had it not been for the other anomalies of the spine.—*A. Steindler, Iowa City, Ia.*

Isolated Fracture of the Pisiform Bone. A. Engel. *Deutsche med. Wchnschr.*, Feb. 19, 1926.

This is a case report of an unusual lesion. The patient, aged sixteen, fell with arm

outstretched striking against the back of the hand. Examination showed marked swelling of the hand, particularly on the ulnar side. No crepitations but marked tenderness in the region of the pisiform bone. The hand was immobilized. Healing occurred very slowly but after five months the pisiform had united and pain had disappeared. In the x-ray picture was seen a separation of the fragments of the pisiform bone with a gap of about one centimeter between them.

Reports of similar lesions are extremely rare. One treated by Pfab reported in Archiv für klinische Chirurgie, CXXIX, required operative removal of one of the fragments of the pisiform before the patient could be relieved.—*Leo Mayer, M.D., New York City.*

Cleft Sternum and Ectopia Cordis. D. M. Greig. *Edin. Med. J.*, XXXIII, 480, August 1926.

A male child was born at full time of healthy parents. In the midline of the thorax was alternately a depressed gutter and a bulging eminence under which the fluttering movements of the heart were palpable and visible. There was no cyanosis, and the child did well until the age of thirteen months when, after symptoms suggestive of slight nasopharyngeal catarrh, he was found dead one morning in his cradle.

Paterson's work on the development of the sternum showed that that bone is developed independently of the ribs. The primary element is the presternum. From this precartilaginous condensation two lateral bands extend caudally to complete the sternum.

The existence of cleft sternum is determined long before the earliest ossific point appears, and that is in the presternum during the sixth month of intra-uterine life.

(1) *Simple cleft sternum* has been described in animals, e.g., the pigeon. A famous case was that of A. E. Groux, aged 25. This was fully described by many authorities. By muscular action he could widen or narrow the groove. A very striking illustration is figured by Curschmann.

(2) *Cleft sternum* associated with ectopia cordis. This defect is incompatible with prolonged life. A case was described by Ogilvie and Cathcart in a lamb where the cleft extended from the neck to the umbilicus. There were abnormalities of the vertebral column of the diaphragm and of a number of viscera. A case was described fully in 1706 by Martinez and others in 1745, 1759 and 1772. When complicated by ectopia cordis, the sternum may be entirely wanting or defective at either extremity. The cardiac condition is the principal one.

(3) *Ectopia cordis without cleft sternum.*

(a) Cervical.
Bland-Sutton figures a case of cervical heart in a calf and Breschet describes a newly born female where the apex of the heart lay between the two halves of the mandible. The sternum was defective in its upper part and there was a congenital diaphragmatic hernia.

(b) Thoracic.

(c) Abdominal. The heart may pass through the diaphragm and rest in a hollow in the liver surface. In one case an umbilical hernia noticed at birth contained the heart.

Fifty-eight cases in all are referred to. Twenty of these are cases of simple cleft sternum.—*Alexander Gibson, F.R.C.S., Winnipeg.*

Late Arthritis after Enteric Fever. E. Michon. Pyo-arthrose du Genou à bacilles d'Eberth, *Bull. et mem. Soc. nat. de Chir.* Paris, LII, 113, 1926 (Abstracted by D.M.G. in *Edinburgh Med. J.*, XXXIII, 636, Oct. 1926).

Male, forty-three, admitted to hospital with swelling of right knee. Onset rapid after bicycling. Aspiration showed thick green pus yielding pure culture of bacillus typhosus. Patient had had enteric fever twenty years before. He had at this time an abscess on the right hand and another on the right tarsus.

The joint was opened, and this was followed by immediate active movement. The condition cleared up leaving some limitation of movement.—*Alexander Gibson, F.R.C.S., Winnipeg.*

Osteochondritis or Epiphysitis, A Review. Arthur C. Christie (Washington, D. C.). *J. Am. Med. Assn.*, LXXXVII, 291, 1926.

A brief review of the theories advanced to explain the cause of epiphysitis is given: namely,—infections, circulatory, following low grade trauma, endocrine disorders and errors in epiphyseal developments. The view accepted by most observers is an aseptic necrosis due to prolonged trauma and directly due to changes in circulation.

There is marked similarity in the pathological process occurring in the several epiphyses. The disease entity is now generally recognized when limited to the femoral head, the tibial tubercle, the scaphoid and the head of second metatarsal.

Vertebral epiphysitis, more frequent than in any other location, is characterized by variation and the time of appearance for the vertebral epiphysis (normally the dorsal show at the eleventh or twelfth year) and by increased thickness and roughening on the margins at both upper and lower, with indistinct outline at intervertebral discs. The clinical symptoms are fatigue, backache and tenderness at various levels. Lateral curvature and particularly round shoulders may be present.—*W. B. Carrell, M.D., Dallas, Texas.*

Osteomyelitis Variolosa. E. J. Huenekens and Leo G. Rigler, Minneapolis. *J. Am. Med. Assn.*, LXXXVII, 295, July 31, 1926.

Chiari, Musgrave and Sison have noted multiple deformities, symmetrical in type, resulting from changes at the epiphysis subsequent to osteomyelitis variolosa. Huenekens and Rigler report an acute illness in a child, 4 years old, with roentgenograms after six weeks showing a symmetrical widespread destructive process in the spine and long bones limited to the end of the diaphyses and adjacent margin of the epiphyses, without injury of the articular surfaces. The clinical symptoms were those of a complicating polyarticular arthritis on the third day. Wrists, elbows, shoulders, knees, ankles and first cervical vertebra were involved and subsided after ninety days. High leucocyte count, temperature 100° to 102° present, but no abscess formation. The final roentgenograms, eleven months after onset, show fusion of atlas and axis with dislocation of second cervical and new bone formation at the various epiphyses. There is beginning closure of the epiphyseal line at the distal end of one tibia. This latter will undoubtedly lead to growth distortion at the ankle.—*W. B. Carrell, M.D., Dallas, Texas.*

Pseudohypertrophic Muscular Paralysis. Preliminary Report of Thirty-Nine Cases. Philip Lewin, Chicago. *J. Am. Med. Assn.*, LXXXVII, 399, August 7, 1926.

Lewin presents a concise review of the known facts regarding muscular dystrophies and believes that, in some cases, there is a definite relation to changes in the endocrine glands. The etiologic factor producing endocrine disorder is likewise responsible for muscular changes. In evidence, improvement has been definite in several cases following administration of epinephrine and secondly, there was associated glandular dystrophy in several cases.

The clinical symptoms resulting from the gradual, increasing muscular weakness should be interpreted without difficulty. Prognosis: poor. Following remissions, may improve, but recovery rare. In a series of thirty-nine cases, marked improvement in seven, moderate in three. Treatment advised: (1) diet rich in vitamins; (2) large doses of calcium lactate in milk; (3) epinephrine, 3/200 gr. t.i.d.; (4) physiotherapy and muscle re-education.—*W. B. Carrell, M.D., Dallas, Texas.*

Removing Splints and Braces from the Patient. Emil S. Geist (Minneapolis). *J. Am. Med. Assn.*, LXXXVII, 486, 1926.

Geist calls attention to the necessity for more definite information as to the time and manner of leaving off apparatus in fracture treatment and in other joint disabilities.

With available statistics, the length of time for the healing period has been fairly established and when this has been determined for the particular case, the surgeon should remove apparatus in such a manner that harmful strain may be avoided.

A simple rule is to discontinue the splint gradually, never abruptly. Permit the

removal for one hour daily for a week; 2 hours daily for the second week; three hours for the third, and so on. The hourly method keeps the patient under observation when relapse or deformity may be checked and better protects subnormal tissues.—*W. B. Carrell, M.D., Dallas, Texas.*

AN OUTBREAK OF POLIOMYELITIS—APPARENTLY MILK BONE. A. C. Knapp, E. S. Godfry, W. L. Aycock. *J. Am. Med. Assn.*, LXXXVII, 635, Aug. 28, 1926.

Eight cases, occurring near the same date, in various parts of the city of Courtland, New York and all drinking milk from the same dairy which supplies only four per cent. of the city's total supply. At this dairy four to fourteen days before the outbreak, a boy milked while ill with acute poliomyelitis.

Practically all cases developed in families of the poorer class and the incidence of contamination compares with typhoid epidemics; that is, one case developed for every thirty quarts of milk delivered from the implicated dealer.—*W. B. Carrell, M.D., Dallas, Texas.*

THE CORRECTION OF DEFORMITY IN QUIESCENT DISEASE OF THE HIP. LeRoy C. Abbott. *J. Am. Med. Assn.*, LXXXVII, 1095, Oct. 2, 1926.

The author presents a series of cases with contraction deformities complicating quiescent hip disease, both tubercular and pyogenic.

First group: Deformity of the hip without ankylosis. In this there is dislocation with flexion, adduction and inward rotation. The indication for treatment is to correct deformity, secure stability and reduce shortening. Operation in two stages: (1) Division of muscles and skeletal traction; (2) Arthrodesis of hip. The traction through a drill, placed as the Steinman pin, is first in the line of deformity and gradually the leg is extended and abducted. When complete, the trochanter, or remaining neck is placed for fusion at the acetabular cavity.

Second group: Deformity, with ankylosis. Correction is made by doing a subtrochanteric osteotomy, but to avoid displacement in extreme cases, the osteotomy is made and traction applied in the line of deformity for twelve to fifteen days, when the soft callous formed will permit gradual correction, without danger of displacing the fragments.

Protective weight-bearing follows.—*W. B. Carrell, M.D., Dallas, Texas.*

THE ETIOLOGY AND PATHOLOGY OF ARTHRITIS. Ralph Pemberton. *J. Am. Med. Assn.*, LXXXVII, 1253, Oct. 16, 1926.

Infections have much to do with causation of arthritis, but other factors operate to precipitate or perpetuate the disease. Arthritis is an expression in the joint of an underlying rheumatoid state active in many other tissues of the body. Sixty per cent. of arthritis cases, in common with some other disabilities, show decreased sugar tolerance which is not diabetic in nature as the sugar is eventually burned. It appears that the rise of oxygen in the blood, revealing a lowered sugar tolerance, could be explained on mechanical grounds.

It has been shown that some arthritic patients have circulatory disturbance, in the nature of capillary stasis, and on relieving this stasis by baking and massage, there is increase in sugar tolerance and improvement in symptoms. Paralleling these observations, it has been possible to produce low sugar tolerance in individuals, normal and arthritic, who had been found to have a normal sugar disposing mechanism, by placing them in dorsal decubitus, with two legs and one arm sharply elevated.

On the hypothesis of capillary stasis and low sugar tolerance, careful studies were made of the corpuscular elements as to changes in morphology or numbers. Seventy per cent. of arthritic patients, compared to forty per cent. of normal persons showed a lowered number of cells in the first blood from a finger prick than was present in subsequent drops. The first drop is not arterial, but comes from capillary beds.

Consideration must be given to the close contact of the synovial fluid with the blood stream by virtue of which glucose injected by mouth may reach concentrations in the synovial fluid higher than in the blood. Likewise, toxins or other deliterious substances have an easy access to the joint cartilage.

Finally, some clinical observations have been made which corroborate the correctness of the above hypothesis. Administration of vasodilators, as sodium nitrite, may be followed by a return to normal sugar tolerance and therapeutic benefit.

Disturbance in the circulation with inactivity, and of pooling of blood in deponent parts adds to the vicious cycle in chronic arthritis.

Rational treatment must include a careful search for and removal of foci of infection; the institution of a low caloric diet and the improvement of the general physiological process, involving the locomotor system, the nervous system, and the gastro-intestinal tract. The proper use of rest, baking, massage and exercises is of great importance.

In selected cases, treatment with vaccines is appropriate and in some, the effect of vasodilated drugs will be beneficial.—*W. B. Carrell, M.D., Dallas, Texas.*

THE ETIOLOGY OF SOLITARY BONE CYST. P. B. Phemister and John E. Gordon. *J. Am. Med. Assn.*, LXXXVII, 1429, Oct. 30, 1926.

The authors review the theories advanced to explain the etiology of bone cysts and, from their study, are convinced that the infectious theory is most plausible. Clinical and pathological appearance simulates a low grade infectious condition.

Two cases are reported showing the gross appearance of bone cysts in which microscopic sections showed inflammatory changes and in which cultures yielded the streptococcus viridans in both cases.—*W. B. Carrell, M.D., Dallas, Texas.*

TARSOMEGALIE. A. Mouchet and T. Belot. *Jour. de radiol. et d'électrol.* X, 289, July 1926.

The child, aged three, is the son of a medical man. His progress has been observed every two or three months since birth.

At eight months it was noticed that the left foot was in valgus position, the medial malleolus prominent and the astragalus projecting under the tibial malleolus and in front of the tendo Achillis. There was no pain or tenderness, no heat, redness or oedema; no signs of rickets. X-ray examination showed left astragalus at least twice the size of the right one; it was much deformed, outline quite irregular, structure irregular, some areas clear, others dense. The tibial malleolus presented the same characteristics. The calcaneum, cuboid and third cuneiform corresponded to those of the right foot. Other radiographic peculiarities noted were the extremely early appearance of centres of ossification in the first and second cuneiform and in the scaphoid bones. These early ossific centres were irregular in outline. The centres for these bones had already appeared by the age of eight months. In addition to this, the first and second metatarsals were one millimetre longer upon the left foot than upon the right.

At eighteen months the valgus condition was more marked and there was atrophy of the left leg and thigh. The astragalus had more than doubled in bulk, the vertical diameter being two and one-half times greater than on the right side.

At twenty-five months, three new radiographic facts were observed:

(1) The architecture of astragalus and tibial malleolus was less abnormal and the outlines of the bones were more regular.

(2) The centres of ossification which had appeared early had a form approaching the normal.

(3) The third cuneiform was enlarged in its transverse diameter.

A special shoe was made for the left foot and the child walked at twenty-two months.

At two years and six months the relative hypertrophy of astragalus and tibial malleolus have persisted. The child walks easily without tiring.

The authors regard this as a congenital condition similar to macrodactyly and have dubbed it "Tarsomegaly". There has been no suspicion of rickets or of infectious disease. Dentition and nutrition have been normal. No explanation is offered for the maldevelopment. As far as known, no similar case has been published. The Wassermann reaction is negative in the child and parents. Treatment by mercury and ultra-violet light produced no effect.

Numerous radiographs accompany the article.—*Alexander Gibson, F.R.C.S., Winnipeg.*

NON-SPECIFIC PROTEIN INJECTIONS IN CHRONIC ARTHRITIS. W. Yeoman. *Lancet*, I, 1246, June 26, 1926.

This article gives an analysis of fifty cases treated by intravenous injection of T.A.B. vaccine.

A resumé of the literature is given and theories of non-specific therapy are discussed. Following Petersen, the author thinks that "the organism is stimulated to greater production of either specific substances anti-bacterial in character, or that the general resistance to intoxication is increased". Hermann and Ling found that "serum antibodies including bacteriolysins for bacillus-typhosus and staphylococcus aureus were shed into the circulation within twenty-four hours after the injection of foreign proteins". It was also found that antibodies, which have gradually disappeared after an infection or following immunization artificially produced, again returned to the serum after any procedure that increased the body temperature. "Hyperthermia has a direct stimulating effect on the previously formed antibodies".

The vaccine consisted of B. Typhosus, two parts, and one part each of B. Paratyphosus A. and B. The dosage varied from an initial dose of 50 millions given intravenously to a maximum dose of 500 millions. In the majority of cases, four days were allowed to elapse between the injections.

No case of anaphylaxis was encountered. The reaction commenced one-quarter to one and a half hours after the injection. The highest temperature recorded was 104.2°. When the temperature is going up there is nausea, headache, backache, and generalized pain in all the joints. With the fall in temperature is associated profuse perspiration and all the unpleasant sensations are replaced by "a delightful feeling of euphoria". This stage lasts from twenty-four to forty-eight hours. The reaction is less severe after successive injections.

Leucocyte counts were done as a routine. There is a leucopenia corresponding to the rigor, then a sharp leucocytosis following the rise of temperature and a return to the previous level in twenty-four to forty-eight hours. The highest count in this series was 27,000, five hours after the injection.

*Dangers and Contraindications.* Two patients became rather excited and confused for a short time on two occasions but they caused no anxiety. There were no other complications in any of the patients. Petersen reports that in old tuberculous or syphilitic lesions the reaction is liable to cause a flare-up of symptoms.

*Results.* Average stay in hospital was four weeks. Forty-four cases discharged as definitely improved. Six were neither better nor worse. Of the forty-four discharged improved, five have become worse, and seven remain as at the time of discharge. The cases that have become worse are associated with a definite focus of infection which was not removed or had achlorhydria.

The author concludes that improvement is possible in eighty to ninety per cent. of cases and this improvement is maintained in fifty to sixty per cent. of cases. If all foci of infection are not removed, the injections do not arrest the disease and the patient will relapse. The cases which do not do well are those of the menopause group, of the chronic villous type, and those showing achylia.

A bibliography is appended.

In discussion of this paper Sundell points out that fever and sweating are the essentials. He makes a plea for the use of the hot pack. This method, in his opinion, while slower, is equally satisfactory.

Ray points out that the toxic material is usually regarded as being made up of proteins and their split products, albumoses and proteoses. The principle underlying the use of foreign proteins intravenously is the stimulation of enzyme activity. This promotes the appearance in the blood of enzymes that have the power of digesting the albumoses and proteoses formed by the acid hydrolysis of the actual proteins introduced.

Besides increased enzyme activity there is stimulation of the bone-marrow, mobilization of leucocytes, and the formation of antibody. Stimulation of the skin by heat produces hyperemia and increased lymph supply. In consequence skin enzymes, such

as lipase and protease, are swept into the circulation.—*Alexander Gibson, F.R.C.S., Winnipeg.*

BACKACHE FROM THE RADIOLOGICAL ASPECT, WITH SPECIAL REFERENCE TO THE DEMONSTRATION OF THE EARLIER, MORE ACUTE STAGES OF SPONDYLITIS DEFORMANS. K. Stewart Cross. *Med. J. Australia*, Aug. 7, 1926.

Spondylolisthesis is practically confined to the slipping downward and forward of the last lumbar vertebra on the sacrum. The articular processes of the sacrum offer the only positive obstruction to this slippage. Normally they make an angle of sixty-five degrees with the median sagittal plane, but may vary from a ninety degree angle, to parallel with this plane. In the latter condition, called the "lumbar type", the antero-posterior view looks directly through the articular interspace; when so arranged, the articular processes offer no hindrance to forward slipping of the last lumbar, the whole strain being borne by the ligaments.

There is also wide variation in the uprightness or flatness of the sacral facets; flat ones may permit forward slipping of the vertebra above. These anomalous arrangements of sacral facets frequently involve one side only, permitting a rotary slipping of the last lumbar through an arc centering in the normal articulation on the opposite side.

In judging the presence or absence of spondylolisthesis, the critical line is that of the dorsal surfaces of the vertebral bodies, which are normally in perfect alignment.

Spondylolisthesis is not very common and may result from falls, lifting heavy loads and so forth. Its severity is often moderate at first, with gradual increase. It may give symptoms very like those of sacro-iliac subluxation, for which it is often mistaken. Another cause of weakness at the sacrolumbar joint is anatomical defect; spina bifida occulta, present in more than four per cent. of spines; and sacrolization of one transverse process of the last lumbar, causing undue fixation on one side, with strain on the other.

Sacro-iliac strain is common but is very difficult to demonstrate radiologically.

A transition in the direction of facing of the articular facets also occurs at the dorso-lumbar junction, the dorsal facets being placed nearly at right angles to the median sagittal plane, like the sacral, while the lumbar facets more or less parallel it.

The last dorsal and the first lumbar may present the dorsal arrangement on one side and the lumbar on the opposite side, causing uneven stresses in bending.

Spondylitis deformans is a very frequent cause of backache and of obscure referred pain. The bony changes, from lipping to complete ankylosis, are well known and readily detected. Recently, demonstrations are being made by x-ray in the earlier stages where only swelling of the spinal ligaments is present, without any calcification.

Instead of passing as a flat band from one body to the next, the lateral spinal ligaments can be seen to present convexity or swelling at the interspaces: later these swollen areas begin to show calcification. This early stage, an "acute ligamentitis", is demonstrable radiologically, the classical spondylitis deformans probably being the end result of this process.—*Edward N. Reed, M.D., Ocean Park, Calif.*

THE SPHENOID AND POSTERIOR ETHMOIDS AS SOURCES OF FOCAL INFECTION USUALLY OVERLOOKED. Amedee Granger, M.D. *New Orleans Med. and Surg. J.*, LXXIX, 318, Nov. 1926.

For the last four years the author has devoted a good deal of time to the skiagraphical study of sphenoids and ethmoids, and he is convinced that these sinuses are often the cause of focal infection. He believes that this focus is not suspected by the physician as there is frequently an absence of local or nasal symptoms and often the patients are not seen by rhinologists.

This is a chronic inflammation sometimes of many months' standing. In the writer's experience, however, the most common pathology is the hyperplastic condition of the lining membrane of these sinuses. Several cases are reported.—*Edward S. Hatch, M.D., New Orleans.*

MULTIPLE CARPOMETACARPAL DISLOCATIONS. Waldemar R. Metz, M.D. *New Orleans Med. and Surg. J.*, LXXIX, 327, Nov. 1926.

One case is reported in which there was a backward dislocation of the entire carpus. Attempts at closed reduction under anaesthesia were unsuccessful. A U-shaped incision with its convexity upwards was made over the back of the hand. The hand was then forcibly flexed and a flat bone skid used to reduce the dislocation as a whole. The wound was closed in usual manner and the patient made an uninterrupted recovery.—*Edward S. Hatch, M.D., New Orleans.*

NEW OPERATION TO CORRECT THE REDUCIBLE PES VARUS. Dupuy de Frenelle. *Paris Chirurg.*, No. 3, p. 126, April 1926.

The following operation has been used by the author to treat a patient, affected with a nervous disease, whose feet were in varus: A heavy tendon of reindeer was passed through the cuboid bone, the internal end across the interossei membrane; then came the correction of the deformity by tying the tendon and burying the knot into a groove over the external malleolus. Three years later the foot was in excellent position, while the other which was not operated upon has become worse.—*Felipe Muro, M.D., Detroit, Mich.*

THE SPONDYLITIS OF MALTA FEVER. H. Roger. *Presse méd.*, July 24, 1926.

Roger, of Marseilles, speaks from experience with a large number of cases of Malta fever. Joints occupy first place among the various localizations of this infection,—twenty to forty per cent. according to one observer; in almost every case according to Cantaloube, an authority on this disease. The arthritis is usually of the acute form; it rarely results in plastic, ankylosing changes or in suppuration. The other recognized form is the subacute, generally ending in a restoration of the joint to normal after a term of weeks or months. The joint becomes involved either during the course, or frequently toward the end of a fever of several months' duration.

The sacro-iliac is the articulation most often involved,—50 of 151 of Cantaloube's cases. Next, in order, are: knee, shoulder, lumbar spine, hip, wrist, hand and finger joints, ankle, dorsal spine, elbow, cervical spine. Pain is extreme in sacro-iliac involvement, occasionally keeping the patient immobilized in bed for a year. In the lumbar region, pain and rigidity are the chief symptoms. Little or no alteration in the vertebrae is shown by the x-ray. Treatment requires, in addition to employment of the specific anti-serum, such local measures as light baths, sun baths or radiotherapy. One patient was much relieved by use of a plaster bed. Epidural injection of lipoiodide in the lumbar region is suggested.—*Roades Fayerweather, M.D., Baltimore, Md.*

COXA VARA ASSOCIATED WITH COXA VALGA (in the same femoral neck). A. Mouchet and C. Roederer. *Presse méd.*, Aug. 4, 1926.

This condition has been noted by the authors in eighteen cases; they say they have not found it previously described. The internal inferior border of the neck is described as ascending in a line suggesting valgus; whereas the external superior border has the outline of a varus deformity. It is said that projection errors, due to rotation of the hips while being x-rayed, have been carefully avoided. In the four cases reported the patients were fourteen and fifteen years old; they complained of limp and pain.

To the present abstractor the reproduced outlines of these hips would seem more simply described as showing a slight upward displacement of the normal coxo-femoral angle—i.e., the distal portion of the neck appears prolonged somewhat in the general vertical direction of the femoral shaft, while the juxtocapital portion is correspondingly more horizontal than normal. A hypothetical explanation of the origin of this condition is offered. The chief factors suggested are a mechanical over-load on a developing neck of diminished resistance, combined with undue muscular tension and with a progressive widening of the wings of the pelvis and a consequent alteration of the inclination of the acetabula.—*Roades Fayerweather, M.D., Baltimore, Md.*

PERIODIC HYDRARTHROSIS. J. Mouzon. *Presse méd.*, Sept. 8, 1926.

The clinical peculiarities of this remarkable cyclic type of intermittent hydrops,

affecting most often the knee joint, have been described already by various observers. Perrin, in 1845, seems to have been the first to have called attention to it. Mouzon, in the present article, supplies an excellent review of the clinical aspects of this affection and of the various explanations that may be advanced regarding the causes that underlie it. With scarcely 100 reported cases, it deserves more study, he says, not only because of its curious evolution and the prevailing ignorance regarding its origin and its successful treatment, but also because the elucidation of its pathogenesis would contribute valuable scientific information. "The only positive data that we have as regards the general conditions governing the appearance of periodic hydrops are the clinical data; they show incontestably the influence of the endocrine secretions upon the intermittent hydrops." The analogy of this condition to angioneurotic oedemata has been pointed out by a number of observers; Mouzon speaks of it as obvious. In conclusion: "The essential characteristic, common to all the forms of the affection, remains the marked periodicity of the attacks, and it is the explanation of this that continues most mystifying. It is certainly related with the life cycle of a parasite; the picture is not that of an infection, and as between one patient and another the interval between the attacks is too variable. . . . Here is a vast, unexplored field for the physiologist."—*Roades Fayerweather, M.D., Baltimore, Md.*

Bone Malignancy from the Roentgenological Aspect. Howard E. Ruggles and Lloyd-Bryan, San Francisco. *Radiology*, VII, 24, July, 1926.

Five types of bone tumors can be recognized from roentgenological evidence:

*Giant-cell tumors*, single, central, non-invading, occurring in the epiphyses of long bones, with a trabeculation suggesting soap bubbles, occurring at ages between 20 and 40.

*Osteogenic sarcoma*, a single lesion, involving cortex, medulla, or both, occurring practically always in the distal end, when in long bones. These growths appear before thirty, recur locally, and produce pain, fever and metastases. Extensions are to lung and brain. Of recorded cases there are three and one-half per cent. of five-year cures. The subperiosteal is the common form, with early elevation of the periosteum and new bone formation at the margin of the growth. Later, erosion of the cortex, involvement of the medulla and a variable amount of calcification of the soft tissue tumor. The medullary form is predominantly destructive, with poorly organized trabeculation.

*Undifferentiated sarcoma*, a purely destructive lesion, with fairly sharp margins, and no bone reactions.

*Endothelioma* occurs in two forms; one similar to osteogenic sarcoma, but farther from the ends of the long bones and with more localized destruction of cortex. The second form has a mottled structure suggesting osteitis deformans or myeloma, and involving a considerable portion of the shaft. It may resemble giant-cell tumor.

*Myeloma* occurs in multiple foci, always in cancellous bone, and commonly in ribs, sternum, vertebrae, skull, pelvis and femur. It deforms bony outline, because of irregular growth; shows coarse trabeculation, and may resemble giant-cell tumor, or endothelioma. Occurs chiefly in males of the fourth or fifth decade.

Of 650 cases recorded in the registry, 26% are giant-cell tumor,
40% are osteogenic sarcoma,
10% are endothelioma,
2% are myeloma.

Any focus occurring in the middle third of the shaft of a long bone, or close to the nutrient artery in a flat one, should be suspected of being a metastasis.—*Edward N. Reed, M.D., Ocean Park, Calif.*

Diagnosis and Results in the Radiation Treatment of Some Medullary Bone Tumors. Ralph E. Herendeen. *Radiology*, VII, 140, August, 1926.

X-ray examination is particularly adapted to the diagnosis of bone tumors. Biopsy is being less often resorted to in these conditions, as its dangers are more fully appreciated. The diagnosis of a bone tumor is reached after demonstration of a bone disease, and exclusion of an inflammatory or trophic origin. Next to be considered are

its nature, whether primary or secondary, its degree of malignancy, and its origin, whether medullary or not.

Medullary tumors located in the ends of bones, at the knee joint, and particularly at the distal end of the radius are most often giant-cell growths. Benign medullary tumors, other than giant-cell, are rare. In doubtful cases, asymmetric enlargement and a hazy or irregular line of demarcation from sound bone speak against a giant-cell tumor and for malignancy. To be differentiated from giant-cell tumors are chondrosarcomas and myelomas. Ewing's tumor has characteristic radiographic appearances: it is simulated most closely by carcinomatous metastases.

Giant-cell tumors react to heavy radiation by redness, swelling, and tenderness, which reach their height in from three to six weeks, and then subside. Chondrosarcomas react to radiation only after many weeks. Ewing's tumor responds to radiation most promptly of any bone tumor. Metastases from hypernephromas show very little response. Some giant-cell tumors seem to have been cured by radiation. This is the method of choice where removal by curettement is not feasible, or would incapacitate for a long period because of extensive weakening of the bone. The author considers radiation preferable to amputation for giant-cell tumor. Its results are most satisfactory in young adults.—*Edward N. Reed, M.D., Ocean Park, Calif.*

Results of Periarterial Sympathectomy in Six Cases of Tuberculosis of the Extremities. R. Fontaine. *Rev. de Chir.*, XLV, 53, 1926.

In three cases of recent active tuberculosis (1 knee, 1 foot and 1 wrist) periarterial sympathectomy was followed by definite exacerbation of the disease. In three older cases the sympathectomy seemed to be definitely beneficial and to hasten the healing.

Leriche feels that sympathectomy is contraindicated in the fungous forms of joint tuberculosis but that it is of benefit in old caseating and fibrous lesions with fistulae.—*J. A. Key, M.D., St. Louis, Mo.*

Eight Cases of Delayed Union and Pseudarthrosis Treated by Periarterial Sympathectomy. R. Fontaine. *Rev. de Chir.*, XLV., 95, 1926.

In four cases of fracture in which union had not occurred at the expected time, periarterial sympathectomy was followed by rapid callus formation and union. In two cases the sympathectomy apparently had no effect as union did not occur, and in one infected compound fracture of the leg the operation was followed by an increase in the infection. The eighth case was one in which sympathectomy was formed four days after osteosynthesis of both bones of the forearm, and union was present six weeks later.

In three bilateral experimental fractures, in which sympathectomy was performed on one side, the union was accelerated on the sympathectomized side.

The author concludes that periarterial sympathectomy accelerates the formation of callus, but that it does not replace osteosynthesis or other surgical procedure for non-union or delayed union and that it is contraindicated when infection is present.—*J. A. Key, M.D., St. Louis, Mo.*

Treatment of Old Luxations of the Patella by the Transposition of the Tuberosity of the Tibia and the Resection of the Lateral Capsule. P. Mallet-Guy and J. Rollet. *Rev. de Chir.*, XLV., 105, 1926.

The authors present Berard's method. The operation is as follows: The skin incision is U-shaped and the flap is dissected up to expose the tibial tubercle, the patella, and the fibrous capsule of the joint. The lateral capsule is opened by a long vertical incision, the dislocation is reduced, and the insertion of the patellar tendon with its bony insertion is transplanted to the inner surface of the tibia. The relaxed mesial capsule is plicated and the defect in the lateral capsule is closed by dissecting up a flap from the fibrous covering on the patellar and quadriceps tendon, turning it over into the defect and suturing it in place. The skin is closed without drainage.

One case is reported. The luxation had been present over a year and the result was excellent.—*J. A. Key, M.D., St. Louis, Mo.*

Fractures of the Forearm. Chas. F. Clayton. *South. Med. J.*, XIX, 798, Nov. 1926.

The surgical anatomy of the forearm is discussed and well illustrated by drawings.

The author deals chiefly with fractures of the shaft of the bones. For cases with overriding and displacement he uses a special splint with traction and countertraction. The principle of the splint is somewhat like a Thomas knee splint. Countertraction is by means of a padded metal band pressing against the biceps, the elbow being at ninety degrees flexion. Two rods run along the forearm and are joined beyond the hand. The position of these two rods varies, depending upon whether the forearm is to be held in mid-pronation or in supination. There is a special hand-piece made of wire attached to the forearm (lower fragment) by adhesive and tied to the lower end of the splint. Countertraction is also afforded by means of adhesive plaster attached to the forearm (upper fragment) and fastened to the upper end of the splint. Cross bands between the bars are used to support the forearm and also to assist in holding the fragments in proper alignment.—*F. G. Hodgson, M.D., Atlanta, Ga.*

ARTHROPLASTY OF THE HIP. W. C. Campbell. *Surg. Gynec. Obst.*, XLIII, 9, July 1926.

This is an analysis of forty-eight operated hips. In selecting cases one must consider the occupation and financial status of the patient, as much time may be required to get a durable joint. The age preferred is between eighteen and thirty, but may be from puberty to about forty-five. Contraindications are tuberculosis, eburated bone following osteomyelitis, recent acute infections, osteoporosis and progressive arthritis deformans. Operation is advisable in ankylosis due to trauma and acute infections, including gonorrhea, sometimes in arrested cases of chronic arthritis. Technique of operation and after-treatment is described in detail.

*Results.* Of twenty-three unilateral cases, seven were not followed long enough to determine final results. Of the other sixteen the results were excellent in nine, fair in two, doubtful in one, return of ankylosis in three, and one died. Bilateral cases included twenty-five operations on thirteen patients, with only five good hips resulting, while five other patients were benefited by some mobility and correction of deformity. Two of the thirteen died. None of the bilateral cases secured good motion in both hips.—*R. W. Billington, M.D., Nashville, Tenn.*

"TENOSUSPENSION" FOR HABITUAL DISLOCATION OF THE SHOULDER. M. S. Henderson. *Surg. Gynec. Obst.;* XLIII, 18, July 1926.

Thirty cases of recurring dislocation of the shoulder operated on at the Mayo Clinic are here reported. Of nineteen cases having capsulorrhaphy only eight were cured. Of eight cases having the Clairmont "sling" operation five were cured. Of three cases in which "tenosuspension" was done, all have remained cured, though these cases are recent.

"Tenosuspension" is a modification of Joseph's operation, the tendon of the peroneus longus being used instead of a strip of fascia lata to suspend the head of the humerus to the acromion process. It is passed through drill holes in these bones. This operation is indicated in anterior, but not in posterior, dislocations. The author believes this preferable to the other procedures used.—*R. W. Billington, M.D., Nashville, Tenn.*

STREPTOCOCCUS IMMUNIZATION OF RABBITS IN PREVENTION OF STREPTOCOCCUS ARTHRITIS. L. H. Mayer and M. L. Schroeder. *Surg. Gynec. Obst.*, XLIII, 176, Aug. 1926.

The organisms used in these experiments were two strains of streptococcus viridans and one of streptococcus haemolyticus, an extract being prepared according to the rapid freezing and thawing method devised by C. O. Melick. Six half-grown rabbits were injected intravenously at three-day intervals with 1 c.c., 2 c.c., and 4 c.c. of the extract. No ill effects from these injections were noted. Twelve days later these six rabbits and three control rabbits were each injected intravenously with living organisms of the same strains, in amounts equal to three-tenths of the twenty-four hour growth of one blood agar slant. All of the control rabbits showed definite arthritis, whereas no symptoms developed in any of the treated rabbits.—*R. W. Billington, M.D., Nashville, Tenn.*